BBC

ROBOT WARS IN SPACE

Who will win the new race to the moon? p36

ASIA EDITION

Knowledge

Vol. 7 Issue 9

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

INCORPORATING BBC SCIENCE WORLD

70 YEARS AFTER HIROSHIMA

How life defied the scientists p70

PPS 1745/01/2013 (022915)
(P) 055/11/2014 ISSN 1793-9836
09
9 771793 983016
SGD 7.50 | PHP 300
THB 240 | NT 200 | RM 16
Regent Media

WE CAN BUILD JURASSIC WORLD p27

CAN YOU STILL CATCH BUBONIC PLAGUE? p60

THE HIDDEN FORTUNE IN OUR SEWERS p64

On the cover

Vol. 7 Issue 9

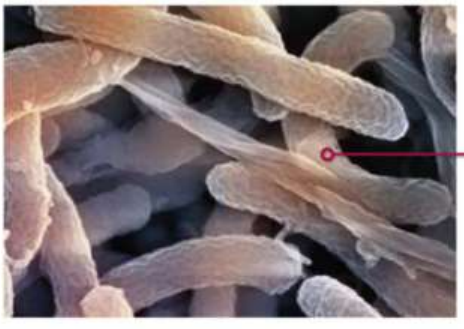
SCIENCE

36 The Robotic Race To The Moon

SCIENCE

27 How We'll Build A Real Jurassic World

SCIENCE



60 Can You Catch The Plague?

SCIENCE

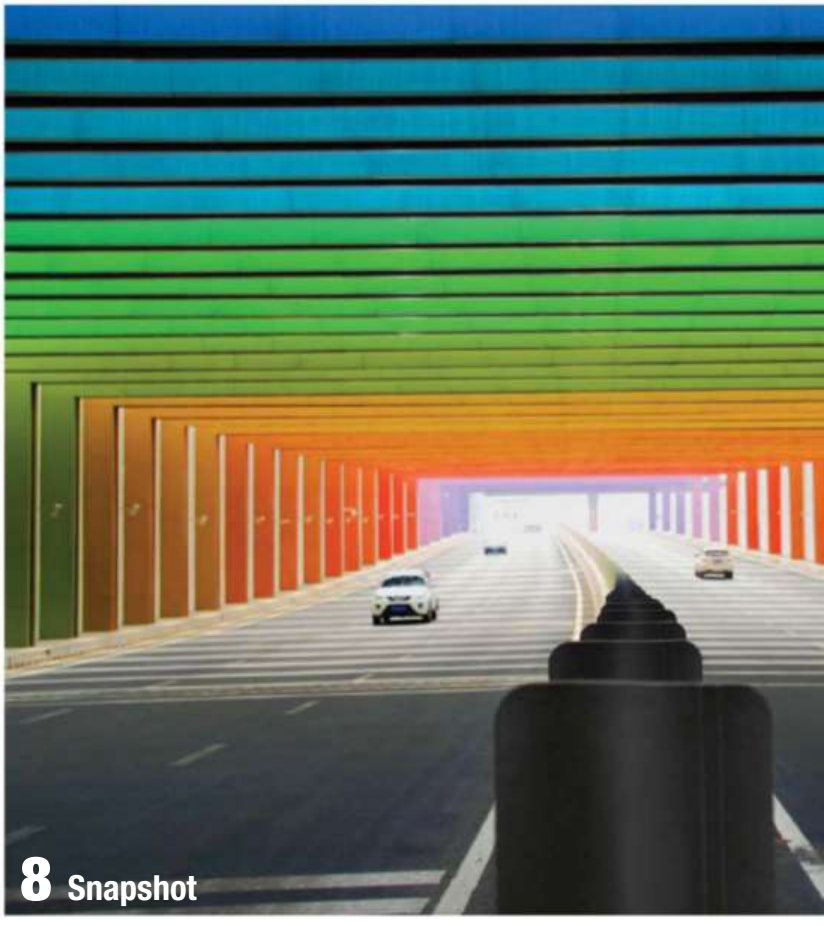
64 Waste Not Want Not

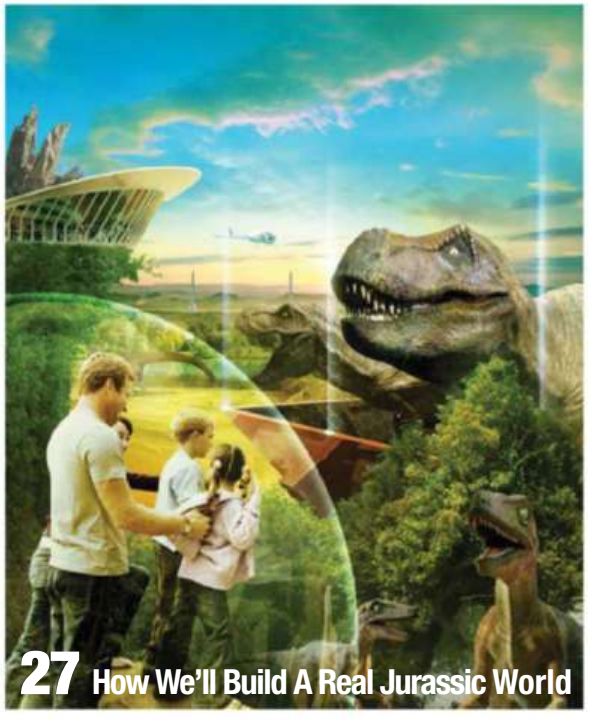
70 Rising From The Ashes

Contents

Vol. 7 Issue 9

FEATURES





elcome

✉ Send us your letters

editorial-bbcknowledge@regentmedia.sg

THE GREATEST VICTORY IS THAT WHICH REQUIRES NO BATTLE

The above is an excerpt from Sun Tzu's The Art of War, an ancient Chinese book on military strategy and science. Unfortunately despite this thought provoking counsel, wars are seldom fought, lost or won without battles or civilian casualties.

It has been 70 years since the US bomber Enola Gay dropped the 'Little Boy' atomic bomb, a contradiction as it was anything but. With a payload of 4,400kg, which translates into 15 kilotonnes of TNT, the first nuclear weapon ever used in war left behind a prolonged trail of unprecedented destruction. Till today, the decision to drop the bomb is a controversial one with many arguing against as well as for that fateful decision that decimated Hiroshima.

But what is quite remarkable was the recovery of the area, despite initial reports that nothing would grow in Hiroshima for 70 years, it took just about a month for red canna flowers to sprout from the rubble, and by spring 1946 Hiroshima's cheery trees were growing again. But for the human survivors, recovery was a long and painful process.

Ben Poon
ben@regentmedia.sg

"LIKE" US ON FACEBOOK! **www.facebook.com/knowledgemagazine**

✉ We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

Experts in this issue…

Brian Clegg

Brian is an award-winning writer of popular science books including Science For Life. On p27 he looks into the possibility of bringing back dinos to roam in a real Jurassic Park.

Hayley Birch

Hayley is a science writer and co-author of The Big Questions In Science. She investigates new technologies that could help put an end to droughts on p40.

Zoe Cormier

Scientists have discovered that we're flushing millions of dollars down our toilets every year. On p64, former environmental reporter Zoe does some digging…

✉ SEND US YOUR LETTERS

Has something you've read in BBC Knowledge Magazine intrigued or excited you? Write in and share it with us. We'd love to hear from you and we'll publish a selection of your comments in forthcoming issues.

Email us at:

editorial-bbcknowledge@regentmedia.sg

We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

BULK SUBSCRIPTION

Having just one copy of BBC Knowledge Magazine isn't enough to go around? Not to worry – Discounts on bulk subscriptions are now available for schools, libraries and organisations who are keen to order more than 50 copies per issue.

For enquiries or to place an order, email to subscribe@media-group.com.sg or call us at +65 6446 6888 today!

BBC Knowledge Magazine, MCI(P) 055/11/2014, ISSN 1793-9836, PPS 1745/01/2013 (022915), is published by Regent Media Pte Ltd under license from Immediate Media Company Bristol Limited.

BBC Knowledge

HERE'S HOW TO GET IN TOUCH

PHONE
Subscription, editorial and advertising enquiries
Tel: 6446 6888 **Fax:** 6449 9945

EMAIL
Advertising enquiries
sales@regentmedia.sg
Subscription enquiries
subscribe@media-group.com.sg

POST
Subscription, editorial and advertising enquiries
Regent Media Pte Ltd
20 Bedok South Road, Singapore 469277

THANKS

Thanks to BBC America and the *BBC Knowledge* channel

A publication of Regent Media

recycle When you have finished with this magazine please recycle it.

mpas Member of Magazine Publishers Association, Singapore

FIPP Member of International Federation of the Periodical Press, UK

Snapshot

Eye candy

Motorists driving through the outskirts of Zhengzhou, China may find themselves dazzled by a flashy new addition: a motorway tunnel that's as bright as a bag of Skittles.

The 400m underpass opened in January and features multicoloured stripes throughout. While there is no doubt that it looks incredible, the spectrum of colours serves a serious scientific purpose: it helps drivers' eyes adjust to the changing light as they enter and exit the tunnel.

"Our eyes are better at seeing bluer colours in dim light," explains Ananth Viswanathan, consultant ophthalmologist at Moorfields Eye Hospital.

"This is because our eyes have two main types of light-sensitive cells – cones for bright light and rods for dim light. The cone system is better at longer red wavelengths whereas the rod system is better at shorter blue wavelengths.

"Having bluer colours in the central dimmer section of the tunnel make sense as colour vision changes at different light levels," he adds.

PHOTO: CORBIS

Growing paints

Despite appearances, crayons do not grow on trees. These colourful evergreens are Eucalyptus deglupta, or 'rainbow eucalyptus'. They grow in sunny equatorial rainforests in the Philippines where great torrents of rain help them to grow as much as three metres in a single season. Once mature, they can reach heights of more than 60m.

Flakes of bark peel off the trees in paper-like sheets at intervals throughout the year. As they do, the bright green hue of the young bark underneath is revealed.

"The newly formed bark is packed with chlorophyll, giving it a green colour," explains Prof Adrian Newton from Bournemouth University. "As the bark ages, it increasingly becomes filled with brown tannins, and the chlorophyll is gradually depleted. This causes the change in colour. Other pigments are likely to be present in the bark, such as anthocyanins for blue and purple, and carotenoids. The latter also provide the red and yellow colours that we associate with autumn leaves."

PHOTO: CHRISTOPHER MARTIN

Through the clouds

On June 18, 1983, Sally Ride became the first American woman to fly in space when the space shuttle Challenger launched on mission STS-7 from Pad 39A at NASA's Kennedy Space Center in Florida. The STS-7 crew consisted of astronauts Robert Crippen, commander, the first two-time space shuttle astronaut; Frederick H. Hauck, pilot; and three mission specialists -- Ride, John M. Fabian and Norman E. Thagard.

This high-angle view of the shuttle liftoff, showing a lengthy stretch of Florida Atlantic coastline and a number of large cumulus clouds, was photographed with a handheld 70mm camera by astronaut John W. Young, who piloted the Shuttle Training Aircraft (STA) for weather monitoring at launch and landing sites for STS missions.

One of Sally Ride's jobs was to call out "Roll program" seven seconds after launch. "I'll guarantee that those were the hardest words I ever had to get out of my mouth," she said later.

PHOTO: NASA

Update

THE LATEST INTELLIGENCE

SUB-ZERO SCIENCE

The trials of research in an area where pens freeze, batteries pack up and faces go numb

HEAD BANGING

Archaeologists may have found the earliest ever murder victim

FIN-TASTIC FISH

Discover why this animal is similar to birds and mammals

THE BIG STORY

FIRST LAB-GROWN LIMB TRANSPLANT

This rat biolimb could revolutionise medicine

Muscle cells are injected into the scaffold of the rat limb

PHOTO: BERNHARD JANK M D/OTT LABORATORY/MASSACHUSETTS GENERAL HOSPITAL CENTER FOR REGENERATIVE MEDICINE

Call it the body shop of the future: a team based at Massachusetts General Hospital has grown a fully functioning rat forelimb and successfully transplanted it onto a living animal. The technique could lead to the development of biological replacement limbs for amputees.

First of all, the team took a limb from a deceased rat and treated it with a detergent to strip away the soft tissue, leaving behind the basic network of bones, veins and tendons.

The basic network of bones, vessels and tendons remained

Next, they re-fleshed the limb using cells taken from the recipient, which greatly reduces the possibility of the limb being rejected. This involved injecting vascular cells into the main artery to regenerate veins and arteries, and injecting muscle cells called myoblasts into the appropriate areas of the 'scaffold' to encourage muscle to grow. After leaving it to develop in a nutrient solution for five days, they electrically stimulated the muscles to further promote formation.

When transplanted onto an anaesthetised animal, the limb quickly filled with blood that was able to circulate normally. To determine whether the muscles were functioning, the team stimulated them with electrical pulses and found the animal's limb could flex.

"The composite nature of our limbs makes building a functional biological replacement particularly challenging," explains researcher Harald Ott. "Limbs contain muscles, bone, cartilage, blood vessels, tendons, ligaments and nerves – each of which has to be rebuilt and requires a specific supporting structure called the matrix. We have shown that we can maintain the matrix of all of these tissues in their natural relationships to each other, that we can culture the entire construct over prolonged periods of time, and that we can repopulate the vascular system and musculature."

The team also successfully stripped baboon forearms of their cells to confirm the feasibility of using this approach for humans. However, the next step will be figuring out how to integrate the transplanted limb's nerves into the recipient's nervous system.

"In clinical limb transplantation, nerves do grow back into the graft, enabling both motion and sensation, and we have learned that this process is largely guided by the nerve matrix within the graft," says Ott. "The next steps will involve replicating our success in muscle regeneration with human cells and expanding that to other tissue types, such as bone, cartilage and connective tissue."

Timeline
A history of transplant medicine

1997

Dr Charles Vacanti from the University of Massachusetts famously creates the earmouse. This rodent has an ear-shaped piece of cartilage grown onto its back.

1999

US surgeon Prof Warren C Breidenbach performs the first long-term successful hand transplant in Louisville, Kentucky. The patient had lost his hand in a fireworks accident.

2011

Surgeons at Sweden's Karolinska University Hospital transplant a trachea into a cancer patient. The trachea is made from a polymer and covered with the patient's stem cells.

2013

A team at Japan's Yokohama University grows tiny functioning human livers using stem cells. Lab-grown organs could eventually solve the problem of organ shortages.

GOOD MONTH/ BAD MONTH

It's been good for:

DOG OWNERS

Want to learn to speak dog? You need the latest software created by researchers in Hungary. The algorithm that the team developed can recognise the age and sex of the dog and could even help to interpret the levels of aggression, fear or distress of the animal.

THE FORGETFUL

These days there's a password for everything: email, bank accounts, online shopping… remembering them all can be a challenge. Well, help may be on the way. A team at New York's Binghamton University has created the 'brainprint' reader – a device that records the unique pattern of brain activity created as a person reads a certain set of words – that could be used in place of a password.

It's been bad for:

BATS

Streetlights may make us humans feel safer at night but they're bad news for bats. Researchers at Lancaster University have found bats are less likely to fly between trees in brightly lit areas creating 'ecological deadzones'. This could lead to less diversity in bat populations.

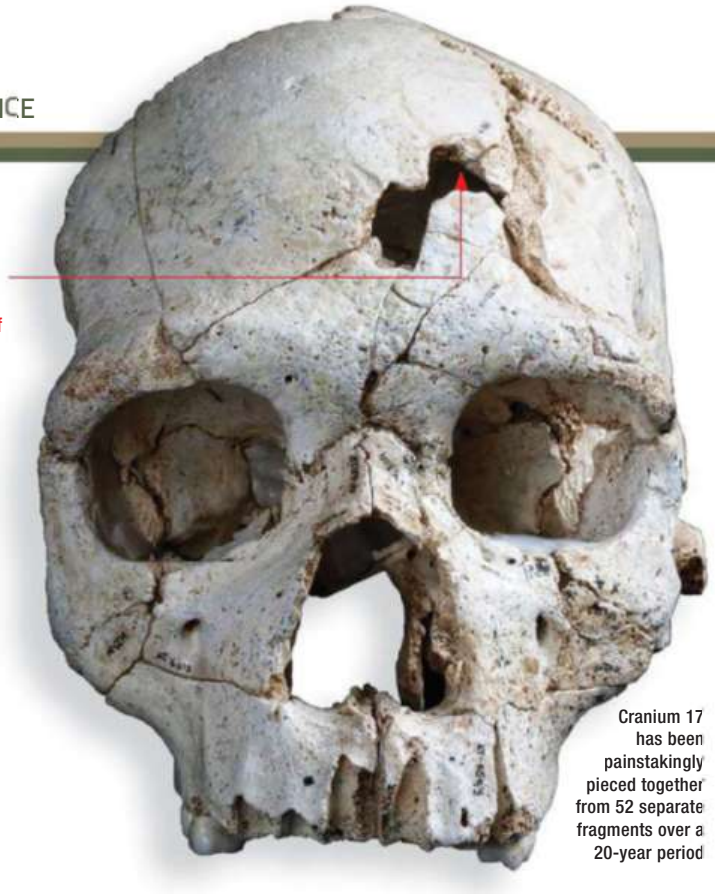
HOUSE SHARERS

If you share your bathroom with others you might want to think about buying a new toothbrush. At least 60 per cent of the toothbrushes tested by the American Society for Microbiology harboured faecal matter. To make things worse, there was an 80 per cent chance that the faecal matter on the toothbrush did not belong to its owner.

PHOTO: BERNHARD JANKA/D/OTT LABORATORY/MASSACHUSETTS GENERAL HOSPITAL CENTER FOR REGENERATIVE MEDICINE, ISTOCK X2, GETTY

ARCHAEOLOGY

First ever murder victim discovered?



Cranium 17 has been painstakingly pieced together from 52 separate fragments over a 20-year period

It's not the nicest way to go: getting bashed on the head twice before being tossed down a cave shaft. But that's what appears to have happened in what could be one of the first cases of murder in human history.

Researchers at Binghamton University have found the remains of some 28 individuals dating back 430,000 years – around the time modern humans are thought to have first appeared – in the Sima de los Huesos ('pit of bones') in northern Spain. Among them was a near-complete skull, named Cranium 17, composed of 52 fragments recovered from a 13m- deep shaft over the last 20 years.

Sima de los Huesos in northern Spain is a treasure trove of ancient bones

Through the use of modern forensic techniques, the team has determined that the two fractures were likely to have been caused by blows from the same object, hitting from slightly different angles around the time of the individual's death. They conclude that the most likely cause of the injuries was an attack by another individual.

Furthermore, if this individual was already dead before reaching the caves, they were likely to have been carried there by other humans. This suggests that early humans are likely to have been responsible for amassing the bodies at the site, potentially providing evidence of funerary behaviour.

"Evidence for interpersonal violence in the human fossil record is relatively scarce, and this would appear to represent the coldest cold case on record," said researcher Rolf Quam. "This is really good evidence for an intentional role for humans in the accumulation of bodies at the bottom of this pit, and suggests the hominins from this time period were already engaging in complex cognitive behaviours."

ASTRONOMY

Milky Way 'weighed' more accurately

There's one OBVIOUS problem facing anyone who wants to weigh a galaxy – you can't just whip out a set of scales and place it on them. Estimations of the mass of our Galaxy, the Milky Way, have therefore included a huge margin of error. But now a team at Columbia University has developed a more accurate method and used it to determine that the mass of the Milky Way is 210 billion times that of the Sun.

The Milky Way consists of roughly 100 billion stars that form a gigantic disc around 100,000 light-years across. The whole thing is orbited by a stream of stars produced by dissolving 'globular clusters'. Through observing the motions of these stars, the team were able to figure out the gravitational attraction created by the Milky Way, and so infer its mass.

"Globular clusters are compact groups of thousands to several millions of stars that were born when the Universe was still very young," said researcher Andreas Küpper. "They orbit the Milky Way and slowly disintegrate over the course of billions of years, leaving a unique trace behind. Such star streams stick out from the rest of the stars in the sky much as contrails from airplanes stick out from regular clouds."

The researchers used data from the Sloan Digital Sky Survey, which scanned the sky from the Northern Hemisphere for 10 years to create a detailed map of the stars in the sky. They focused on the stream produced by a globular cluster named Palomar 5, which had a pattern of wiggles in its path caused by our Galaxy's gravitational pull.

By creating millions of models of our Galaxy using Columbia's Yeti supercomputer, the researchers were able to find a match and estimate the Milky Way's mass with an uncertainty of just 20 per cent, compared to the previous 400 per cent.

The Milky Way may be home to as many as 100 billion planets

PHOTO: JAVIER TRUEBA/MADRID SCIENTIFIC FILMS, ISTOCK

The perils of sub-zero science

DAVID SHUKMAN
The science that matters

The Lance was deliberately embedded in the Arctic pack ice, to monitor how it changes over the course of a year

Research can often be done in the warmth of a laboratory. But to study how the Arctic is changing, you need to be prepared to brave some punishing conditions.

On a recent visit to film a Norwegian expedition 800km (500 miles) from the North Pole, the cold was so intense that batteries that should have lasted hours lost all power in a minute, and on one particularly brutal day, when the wind chill was -47°C, icicles formed on our eyelashes. I tried to write some notes but my biro froze, and my face was so numb I had to massage it before trying to record a few words on camera.

We were there to report on research into the state of the Arctic Ocean as the region warms at twice the rate of the rest of the world. Earlier this year, the maximum extent of the winter sea ice was the lowest since records began more than 30 years ago. No one can tell when summers will see no ice at all at the roof of the world, but to improve forecasts for when that might happen, the Norwegian Polar Institute set out to monitor the life cycle of the ice as it forms in winter and melts in summer.

Its research vessel, The Lance, was deliberately jammed into the pack ice to provide scientists with a ringside seat, and we saw how they diligently measured the ice – data that will help to calibrate readings from planes and satellites. The irony is that, despite our living in the space age, a lot of research still involves a pick and shovel. To deploy tracking devices, to verify the snow depth or to check the thickness of the ice, you need to dig a hole, and I got roped in too.

The scientists were adamant that their task was simply to gather the most reliable information, not to jump to any easy conclusions about global warming. But all the signs suggest that the ice is becoming thinner, and that the Arctic wildlife is responding. Change on this scale could affect patterns of global weather. The timing remains uncertain, but a pretty dramatic transformation seems to be under way.

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

PHOTO: PAUL DODD/NORWEGIAN POLAR INSTITUTE, GABRIEL LICINA

WHO'S IN THE NEWS?

Gabriel Licina
Biochemist and 'biohacker'

Er… what's a biohacker?
Citizen scientists who conduct DIY experiments such as implanting 'enhancements' such as magnets into their bodies. Based in Seattle, Licina was co-founder of a now-defunct group of biohackers called Science for the Masses.

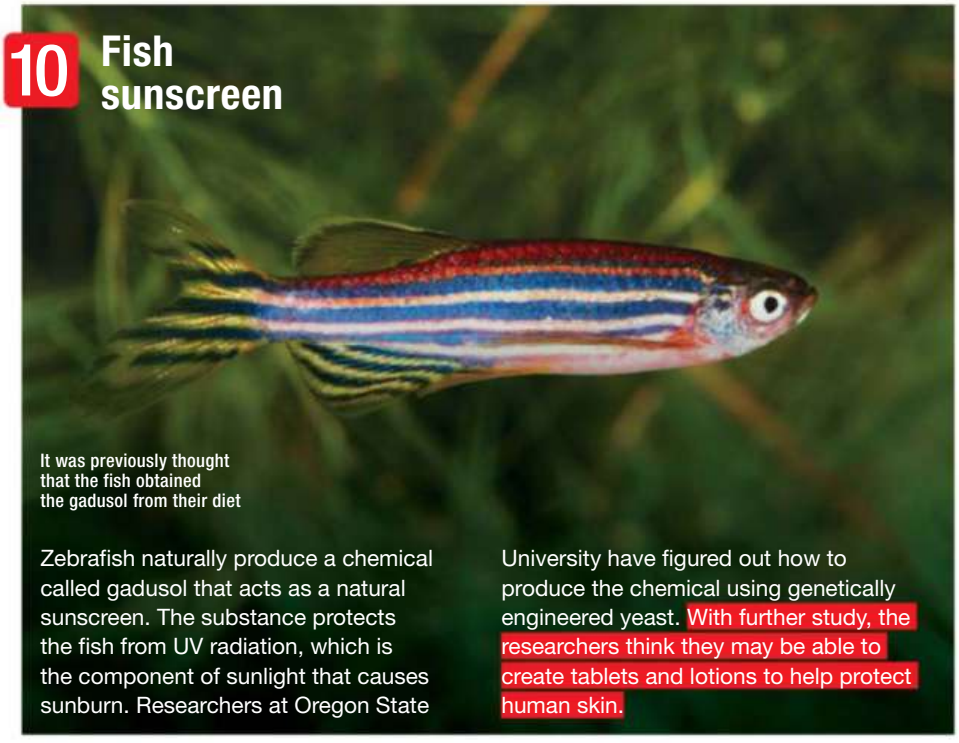
So what's he been up to?
He had his friend drop a solution of Chlorin e6 (Ce6), a chemical that's similar to chlorophyll, into the conjunctival sac of his eyes.

That sounds dangerous… why on Earth did he do that?
Remarkably, it improved his ability to see in the dark. In tests in a dark forest, he was able to spot people standing up to 49m way. Apparently, the substance influences the way light-sensing rods function in the retina.

Even so, we probably shouldn't try this at home, right?
Right. The researchers say that the substance could affect the cellular structure of the eye. Regardless, deliberately putting chemicals into your eyes is not a sensible thing to do and is generally best avoided.

10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 Fish sunscreen



It was previously thought that the fish obtained the gadusol from their diet

Zebrafish naturally produce a chemical called gadusol that acts as a natural sunscreen. The substance protects the fish from UV radiation, which is the component of sunlight that causes sunburn. Researchers at Oregon State University have figured out how to produce the chemical using genetically engineered yeast. With further study, the researchers think they may be able to create tablets and lotions to help protect human skin.

9 Fat-fighting flora

Need to lose a few pounds? Celastrol, a compound extracted from the thunder god vine, has been found to reduce food intake and cause a 45 per cent decrease in the bodyweight of obese mice. Harvard researchers discovered that the compound enhances the action of an appetite-suppressing hormone called leptin and could be developed into a drug to treat obesity.

Eat this to get a Zeus-like body

8 Ultra-light metal

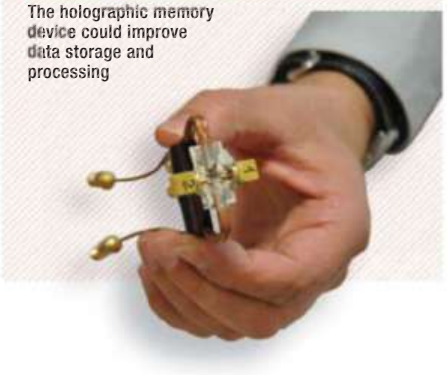
This might float your boat: engineers in New York have created a metal composite less dense than water. The material consists of a magnesium alloy framework peppered with hollow silicon carbide spheres and could be used to build cars, boats or lightweight aquatic vehicles.

The floaty metal won't be available as a bath toy

7 Holographic speech recognition

Fed up of your smartphone's voice recognition mistakes? A team at the University of California has created a holographic device capable of storing and searching through millions of patterns in as little as 100 nanoseconds. It is 'spun' by dissolving proteins in water and could be used to greatly improve speech and image recognition hardware.

The holographic memory device could improve data storage and processing



6 Wearable screens

Hipsters take heed: the tattoo of the future will be electronic. Researchers in Seoul have created an ultra-thin LED display from quantum dots that can be placed directly onto skin like a sticker. It has a resolution of 2,500 pixels per inch and could be used as a wearable screen for smart devices.

The display is far superior to others on the market

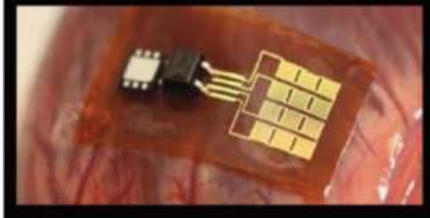
PHOTO: ISTOCK, ERIC SMITH, JOHN ROGERS/UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN, ANTOINE CULLY, MIT, MAX HAMEDI, UC RIVERSIDE, NYU POLYTECHNIC SCHOOL OF ENGINEERING

5 Wi-Fi light bulbs

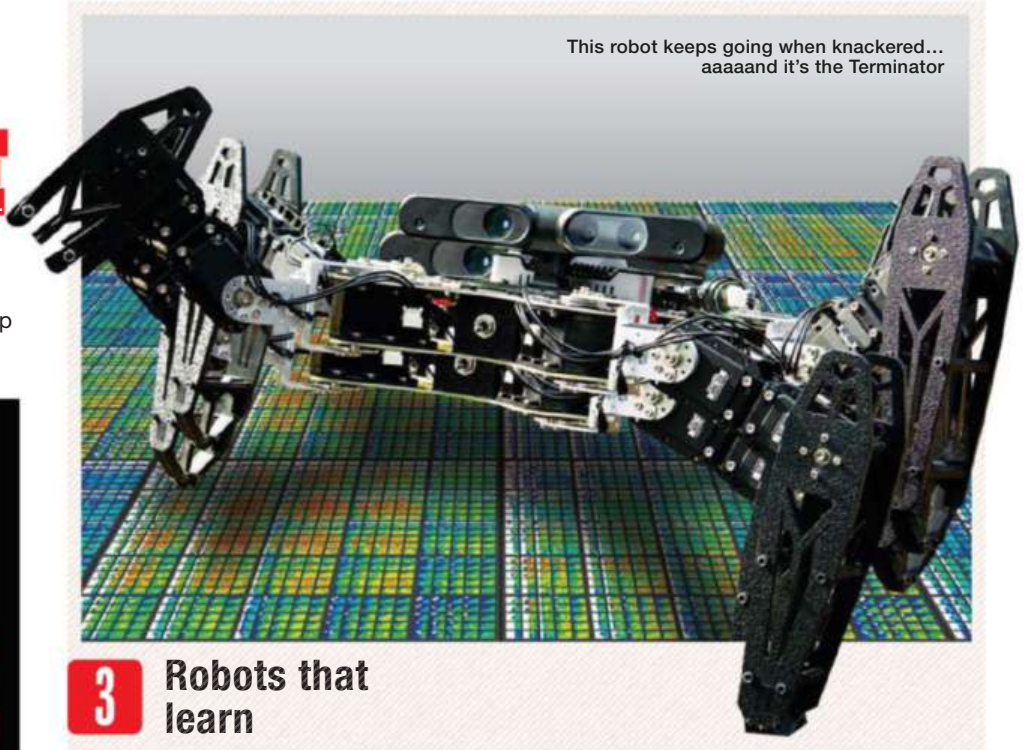
Now here's a bright idea. A team in Malaysia has come up with an interesting way of improving indoor Wi-Fi coverage: using fluorescent light tubes as antennas. The technique takes advantage of the fact that the plasma inside the tubes has conducting properties similar to a regular metal antenna. This technology could help eliminate dead spots in buildings.

4 Personal energy

A team in the US has created thin, flexible devices that can harvest energy from body movements. The technology could be used to power biomedical implants or wearables.



The devices are made of lead zirconate titanate



This robot keeps going when knackered… aaaaand it's the Terminator

3 Robots that learn

Robots that 'learn' how to recover from damage have been created by a team at the University of Wyoming. The technology could be used in more effective autonomous robots for use in everything from rescue missions to care for the elderly. It works by using a trial and error algorithm. For example, after damaging two of its six legs, one of the robots was able to figure out the most effective way of moving using its remaining limbs in just a few minutes. The research was inspired by the ways in which animals learn how to walk after losing a leg.

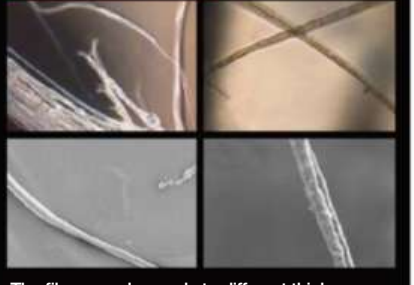
2 Wooden batteries

Your next car could be powered by wood. Researchers from Sweden have used nanocellulose taken from wood pulp to create a flexible, high storage battery. It could be used in electric cars or even in smart clothing. The team processed the nanocellulose fibres to create an elastic, foam-like material. This was then treated with a conductive ink to produce a 3D battery. The battery's structure enables the storage of significantly more power in less space than conventional batteries.

Despite being soft and squishy, the battery is still strong

1 Synthetic spider silk

As far as wonder materials go, spider silk is one of nature's finest. Now, researchers at MIT have figured out how to recreate it in the lab. The team genetically modified bacteria to produce the same proteins used by spiders. It could be used in biomedical applications such as sutures and replacement organs.



The fibres can be made to different thicknesses

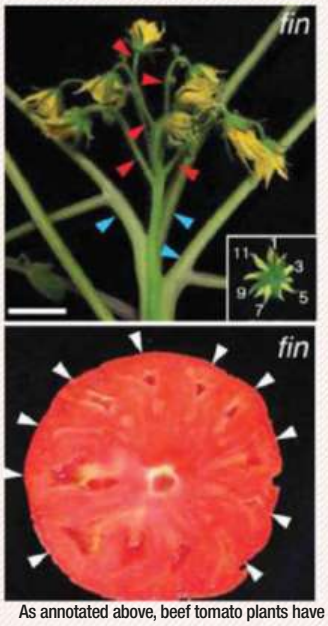
1 MINUTE EXPERT
Methyl-adenine

What's that, a new smartphone?
Way off. It's actually the gene that's responsible for making beef tomatoes much bigger and, er, beefier than their more modestly proportioned relatives.

How does it work?
As a team at Cold Spring Harbor Laboratory in New York recently discovered, CLAVATA3 inhibits stem cell production in tomatoes. Mutations in this gene cause the fruit to produce more stem cells than usual, resulting in the formation of gigantic beef tomatoes.

What can it be used for?
By manipulating the mutations in CLAVATA3, the researchers say it is possible to fine-tune the size of the tomatoes.

Would it work in other plants?
Yep. The gene is present in all plants and may work in the same way. So look forward to a future filled with giant fruit for all.



As annotated above, beef tomato plants have extra branches, while the fruits contain more seed compartments than their wild relatives

PHOTO: NOAA X2, BIOCARBON ENGINEERING, RAINIS VENTA, LIPPMAN LAB/CSHL

Among other benefits, having warm blood makes opah less susceptible to fungal infections

ZOOLOGY

Warm-blooded fish discovered

Meet the opah, the first fully warm-blooded fish known to science. The large, silvery-orange creature, also known as the sunfish, moonfish or Jerusalem haddock, lives hundreds of metres beneath the surface in chilly, dimly lit waters, where its warm blood gives it a competitive advantage over its cold-blooded rivals. Fish that inhabit such cold depths tend to be slow and sluggish, but the opah constantly flaps its wing-like fins to heat its body, which helps to speed up its metabolism, movement and reaction times.

"Before this discovery, I was under the impression this was a slow-moving fish, like most other fish in cold environments," says Nicholas Wegner of the USA's National Marine Fisheries Service, who was lead author of the paper in Science that revealed the findings. "But because it can warm its body, it turns out to be a very active predator that chases down agile prey such as squid, and can migrate long distances."

Wegner realised there was something different about the opah after noticing an

THEY DID WHAT?!
Researchers create a part-human yeast

What did they do?
Though yeasts are made of just a single cell, compared to the trillions of cells that make a human, we share thousands of similar genes with them. Four hundred and fifty of these are essential for the survival of yeast. Researchers at the University of Texas replaced the yeast version of each of these with the human version, creating hundreds of new strains of yeast, each of which included a single human gene.

What did they find?
Nearly 50 per cent of the 'humanised' yeasts that the Texas researchers created survived, and were even able to reproduce. This shows that, thanks to the stability of DNA, yeast and humans retain their links to a common ancestor – even after billions of years of independent evolution.

Some opah species can grow up to two metres in length. Nicholas Wegner for scale

unusual network of blood vessels in its gill tissue. Vessels that carry warm blood into the fish's gills, he discovered upon closer inspection, wind around those carrying cold blood back to the body. This acts like a heat exchanger, transferring warmth from the warmer to the colder blood.

This means it can keep its body at higher temperatures than the surrounding environment, in a manner similar to mammals. A few other fish such as tuna and some sharks were already known to be able to warm specific parts of their bodies, such as muscles, to boost their swimming performance. But none of them do this anywhere near as effectively as the opah.

"Nature has a way of surprising us with clever strategies right where you least expect them," Wegner says. "It's hard to stay warm when you're surrounded by cold water but the opah has figured it out."

Why did they do it?

The work could be used to study diseases caused by genetic mutations. By comparing different strains of yeast with different versions of the same human gene, researchers could study how such mutations affect a person's health. The work could also have applications in testing new drugs.

Yeast cultures growing on an agar plate. They don't look very human…

PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

Clever crockery

On a diet, but fed up with tracking your meals? The SmartPlate can do it all for you. Created by US company Fitly, the plate's three embedded cameras snap the contents of your meal and send the images to a smartphone app, where object recognition algorithms identify your grub. Built-in load sensors also weigh the food, telling you the exact nutritional value of what you're eating. The app even recognises restaurant meals, so there's no getting away with that cheeky cheeseburger.

True colours

Colour vision deficiency can make TV confusing: a recent Champions League match left many viewers baffled when an all-red Liverpool took on all-green Ludogorets. But now there's a simple adaptor from UK company Spectral Edge to remedy this. Eye2TV plugs into the back of any TV with an HDMI socket and tweaks on-screen reds and greens so they're easily distinguishable. The effect is barely perceptible to colour-normal people, so everyone can watch the same programmes.

Patent application number: WO2015004437

Sown by drone

With the world's rainforests disappearing faster than we can replant them, the race is on to find an effective way to save our trees. So how about firing seeds from the sky using an army of drones? That's the solution proposed by NASA engineer Lauren Fletcher and his team at BioCarbon Engineering. The unmanned drones will first create a detailed map of the terrain, so that the right plant can be dropped in the right location. Then they will go about reforesting the area, zipping along just three metres above the ground. At each planting site, a pre-germinated seed will be fired towards the soil, with the seed encapsulated in a hydrogel so that it has all the nutrients it needs to grow into a healthy tree.

With two operators, the team aims to plant around 38,000 trees per day – 10 times the rate of hand-planting. Eventually, they hope to ramp this up to a billion trees a year.

Patent pending

EARTH

Climate change not slowing down

It seems that climate change deniers may have to rethink their favourite argument: global warming has not gone through a pause or hiatus as once thought.

A study carried out by the National Oceanic and Atmospheric Administration (NOAA) has found that global warming has been happening just as quickly in the last 15 years as it did in the latter half of the 20th Century. The apparent pause was due to gaps in the data.

"Adding in the last two years of global surface temperature data and other improvements in the quality of the observed record provide evidence that contradicts the notion of a hiatus in recent global warming trends," says the NOAA's Thomas R. Karl. "The rate of warming over the first 15 years of this century has been as fast or faster than that seen over the last half of the 20th Century."

The study contains more measurements of both sea surface temperature and air temperature on the land. The NOAA researchers also used data that had been collected from buoys, which was significantly more accurate than that collected from ships.

"In regards to sea surface temperature, scientists have shown that data collected from buoys are cooler than ship-based data," explains researcher Thomas C Peterson. "To accurately compare ship measurements and buoy measurements over the long-term, they need to be compatible. Scientists have developed a method to correct the difference between ship and buoy measurements, and we are using this in our trend analysis."

At regular intervals, research buoys transmit data via satellites

BIOLOGY

Light reactivates lost memories

A team at MIT is shedding light on how memories are recalled, in research that could lead to more effective treatments for amnesia or degenerative brain disorders. The researchers are using a technique called optogenetics, which involves adding proteins to neurones (nerve cells) to allow them to be activated by light.

In 2012 the team found that groups of neurones in the hippocampus undergo enduring chemical changes when the brain acquires a new memory. If they are then reactivated by a trigger such as a sight or smell, the memory is recalled. These neurones are known as 'memory engram cells'. The process of learning and experience involves the strengthening of synapses, the structures that let neurones send signals to one another.

This effect is known as long-term potentiation (LTP). But by administering a compound called anisomycin – which prevents neurones from synthesising proteins – after mice had formed a new memory, the team was able to prevent the synapses from strengthening, so when the team attempted to reactivate the memory a day later using an emotional trigger, they could find no trace of it. "Even though the engram cells are there, without protein synthesis those cell synapses are not strengthened, and the memory is lost," explains researcher Susumu Tonegawa.

However, when the researchers used optogenetic techniques, they found that the mice exhibited all the signs of recalling the memory in full.

"If you test memory recall with natural recall triggers in an anisomycin-treated animal, it will be amnesiac, you cannot induce memory recall," Tonegawa says. "But if you go directly to the engram-bearing cells and activate them with light, you can restore the memory."

Groups of neurones in the brain's hippocampus experience chemical changes when memories are created

PHOTO: JAMIE MONCRIEF/UNCW, SCIENCE PHOTO LIBRARY

Why lazy gardeners should start watering their plants

Potted plants can be ungrateful things. I've usually got a bit too much on the go, and the nice thing about plants is that you can get on with being busy for a while and they'll probably still be alive when you come back.

But when you bounce along with your watering can after a period of (let's be honest) neglect, full of good intentions to make it up to them, they often reject your offerings. This week, I noticed the dry soil around the herbs on my balcony, and went out with water to help. But the water sat in jaunty droplets on top of the soil, and as I added more, the droplets joined together and flowed out to the sides, leaving seemingly untouched dry soil in their wake. It's a weird thing to watch, and it only happens when the soil is dry to start with. I've seen this happening for years (I've neglected a lot of plants in my time), but it was only this week that it really occurred to me to wonder what was going on.

With my physicist hat on, it seems that this is what you'd expect from a hydrophobic material (one that repels water). But soil can't be hydrophobic – one of the main reasons that plants can grow in it is that it's fantastic at transporting and holding water. Soil is made up of specks of rock, organic material and microbes mixed together with gaps in between, and water seeps into all those tiny holes and tunnels really easily. Those gaps act like the pores in a kitchen towel soaking up a spill, and water will creep along the surfaces, filling in the gaps as it goes. Any plants parked in the soil will have access to whatever water is nearby, because the soil acts like a sponge and holds the water in.

I didn't give up on watering the parsley, because I know how to get around the problem. You make a little dip in the soil and fill that with water so that it can't run off immediately. And after a few seconds, it seeps in, wets the soil, and then when you pour more water on it's taken up immediately. But this sounds like Catch-22 – if the soil is only hydrophobic when it's dry, how do you get it wet enough to make the problem go away?

After a bit of investigation, I found that the problem occurs when the amount of water in the soil falls below approximately a quarter of the total volume. At this point, the soil particles become coated with lipids and wax that are produced by either the plant or the microbes around it. Oily and fatty substances repel water, so the water droplets just sit on top of the dry and waxy soil. If you get those coatings wet for long enough, they change and the water can touch the minerals or organic matter directly. The uncovered surface can then stick to the water molecules, and the water can begin creeping into the pores and down into the soil. The details of these coatings are still a bit of a mystery, even though it's an important problem for farmers in hot countries. If you have dry, water-repellent soil, the rains may come, but the water will simply run over the top into the nearest stream and be wasted.

"The molecules are also assembling a reprimand to lazy plant-carers like me. Get that watering can out more often!"

It's weird to think of tiny organic molecules shuffling around the soil as it dries out, building up a waxy wall between the soil particles and the air. But as well as constructing a coating, the molecules are also assembling a reprimand to lazy plant-carers like me. Get that watering can out more often! ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

ILLUSTRATOR: ANDREW LYONS

Want To Be In The Know? Join The Club.

SAVE 15%

OFF YOUR SUBSCRIPTION!

4 EASY WAYS TO SUBSCRIBE:

GO ONLINE*

e-SHOPPING.SG

OR EMAIL
subscribe@
media-group.com.sg

FAX TO
SINGAPORE
65-6449 9945

MALAYSIA
603-42926251

CALL HOTLINE
SINGAPORE
65-6446 6888

MALAYSIA
603-79548989

BBC KNOWLEDGE MAGAZINE SUBSCRIPTION OFFER

YES! I WANT TO SUBSCRIBE!

SPECIAL SUBSCRIPTION OFFER!

GREAT REASONS TO SUBSCRIBE

- Every issue delivered direct to your door
- Exclusive subscriber-only offers and discounts

PLEASE TICK ACCORDINGLY

❍ Singapore, 1 year subscription, 12 issues for S$77

❍ Malaysia, 1 year subscription, 12 issues for RM160

***Rates are inclusive of postage in SGP and MY**

PERSONAL PARTICULARS

Title _____ Surname _____

Name _____

NRIC _____ DOB _____

Tel Number _____ Mobile _____

Email _____

Address _____

Country _____ Postal Code _____

MY PROFILE

Gender	Age Group	Occupation	Annual Income
❍ Male	❍ Below 30	❍ Executive	❍ Below $50,000
❍ Female	❍ 31 - 40	❍ Management	❍ $50,001 - $100,000
	❍ 41 - 50	❍ Professional	❍ $100,001 - $150,000
	❍ Above 50	❍ Businessman	❍ Above $150,000

YOUR PAYMENT OPTIONS

❍ CHEQUE

Please enclose a cheque made payable to:
Singapore: Regent Media Pte Ltd
Malaysia: Regent Media Sdn Bhd

Cheque No.: _____

Amount: _____

❍ CREDIT CARD* (VISA & MASTERCARD ONLY) **Singapore only*

Debited amount under"Golf Events and Marketing" will be reflected in your credit card statement for subscribers in Singapore.

Name on Credit Card: _____

Credit Card No.: _____

Expiry Date: _____

Amount: _____

Signature: _____ Date: _____

TERMS & CONDITIONS:
- This subscription offer is non-refundable
- Promotion is valid till the end of September 2015
- Subscription gifts where applicable are available on a while stocks last basis
- The above subscription rates are only applicable to readers residing in Singapore & Malaysia
- Gifts must be taken as provided and are neither transferable nor exchangeable for cash
- Company reserves the right to replace gift when stock is unavailable
- All prices are inclusive of GST and taxes
- Please allow 4-6 weeks for processing
- Subscribers/Winners will be notified by post
- Subscription gifts/lucky draw prizes are to be collected at address stated on notification letter
- Other terms and conditions apply

MAIL TO
Regent Media Pte Ltd, 20 Bedok South Road, Singapore 469277
or
Unit 6.02 Level 6, Menara Maxisegar
Jalan Pandan Indah 4/2 Pandan Indah
55100 Kuala Lumpur.

BUY ANY 3 MAGAZINE SUBSCRIPTIONS FROM

E-SHOPPING.SG

AND GET A FREE GIFT BUNDLE WORTH S$192

- Laneige White Plus Renew Trial Kit (5 items)
- Set of 5 Asian Geographic Junior Limited Edition Books
- Scanpan Knife Sharpener
- Lonely Planet's Best Ever Travel Tips
- Insight Guides-Shanghai Step by Step: The City's Best Walks and Tours
- Hypergear Dry Bag (20 Litre)

SG 50 PROMOTION!

Choose from 15 magazines, including famous brands such as Asian Geographic, BBC Knowledge and Lonely Planet Magazines. Fuel your passions from scuba diving, food to interior design and architecture with our locally produced award winning magazines!

TERMS & CONDITIONS: The SG50 Subscription Promotion expires on 30th September 2015. For 3 or more magazine subscriptions made via e-shopping.sg, the subscriber will be entitled to a free Gift Bundle (while stocks last). The Gift Bundle will be available for collection (postage is not included) from Media Group Head Office at 20 Bedok South Road, Singapore 469277. For enquiries please contact lauren@media-group.com.sg.

HOW WE'LL BUILD A REAL JURASSIC WORLD

The ***Jurassic Park*** series has captured our imagination, Brian Clegg finds out if we really could bring extinct animals back from the dead…

Scan this QR Code for the audio reader

ILLUSTRATOR: ANDY POTTS

HOW TO BRING BACK EXTINCT CREATURES

Dinosaurs have captured our imaginations for decades, but recreating them is a formidable challenge. Jurassic Park author Michael Crichton suggested getting dino DNA from blood-sucking insects that had been preserved in amber. The good news is that amber (fossilised tree sap) does sometimes contain well-preserved insects. The bad news is we can't get useful DNA this way. The problem is the half-life of DNA molecules.

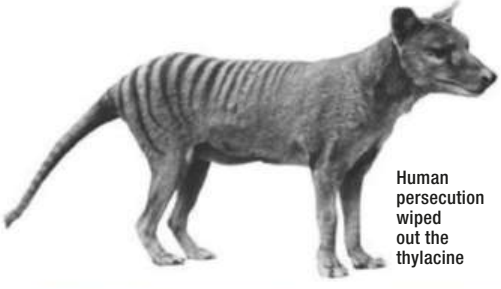
DNA is a complex, fragile substance. Over time it breaks down, becoming less and less readable. A team from the University of Copenhagen and Murdoch University in Perth found that in 521 years, half of a sample of DNA would be broken into useless fragments, after another 521 years another half and so on. This means that no part of a DNA sequence would be readable after 1.5 million years – far less than the 60 million plus required for resurrecting a dinosaur. Furthermore, a team at Manchester University that tried the insect-in-amber technique found that DNA degraded faster than normal in these conditions.

But there is hope for recently extinct mammals like the thylacine (Tasmanian tiger), which died out in the early 20th Century, or even 5,000-year-old mammoths, found preserved in permafrost. Not only can researchers find intact DNA to use, but there are also closer living relatives to act as host mothers. In fact, Prof Michael Archer of the University of New South Wales believes bringing back the thylacine is a distinct possibility.

"I'm hopeful, given the increasing frequency of major technological breakthroughs in synthetic biology, that it will be within the next 20 years," he says.

Some believe we will never clone a mammoth, despite there being two projects underway attempting just this. Other experts such as Dr Beth Shapiro, Associate Professor of Molecular Evolution at the University of California, Santa Cruz, are cautiously optimistic.

"It depends on what you are willing to call a mammoth," she explains. "If you are willing to accept an Asian elephant whose genome contains a very small amount of mammoth DNA – perhaps a few mammoth genes inserted in place of the elephant version of genes, so that an elephant is better able to survive in a cold place – then this could happen quite quickly. For mammoth de-extinction, the biggest challenge is probably not sequencing and assembling DNA or editing an elephant genome so that it



Human persecution wiped out the thylacine

Preserved bodies of thylacines still contain viable DNA

PHOTO: GETTY X2, KRIS KRUG/FLICKR, JENNIFER DOUDNA/UC BERKELEY ILLUSTRATOR: ANDY POTTS

Dr Beth Shapiro thinks that reverse engineering could help with de-extinction

looks more mammoth-like, but the later stages: implanting a developing embryo in a surrogate mom, having that pregnancy develop to term, rearing a newborn calf. These are challenges that not only do we not know how to solve, but that, ethically, remain questionable."

It would be remarkable if these extinct mammals were brought to life – but it isn't Jurassic World. Dinosaurs have a unique fascination and are the most attractive possibility for creation. And although it is not currently possible, what is proposed is 'dinosaur lite'. This would be a hybrid of an existing animal and a dinosaur.

Starting with the DNA of an animal descended from dinosaurs – a big bird, for instance – scientists would try to produce the characteristics we know, or suspect, dinosaurs had by genetic engineering. The result might be something that looked and acted like a Tyrannosaurus rex, but that would not truly be one.

"CRISPR, Clustered Regularly Interspersed Short Palindromic Repeats, are short gene-like sequences. They are often associated with a particular enzyme, Cas," explains palaeontologist Dr Henry Gee. "The CRISPR-Cas system – found naturally in bacteria – is a kind of immune system, allowing bacteria to resist invasion by viruses. In the past couple of years, it's become evident that the CRISPR-Cas system can be used for the precision editing of genetic material… in the science-fictional world of dinosaur genome reconstruction, it would be an essential part of the toolkit."

It might seem that an approximation to a dinosaur would be a pretty worthless animal, but Gee disagrees. "Given that almost everything we know about dinosaurs comes from bones, and everything else is a matter of guesswork anyway, who's to notice the difference?" he asks.

Dino hybrids would allow researchers to explore the realities of dinosaur life, which currently we can only guess at from the fragmentary remains we have.

But not every expert is hopeful of success. Michael Benton, Professor of Vertebrate Palaeontology at the University of Bristol, thinks that practicalities would overwhelm any attempt to manufacture a dinosaur.

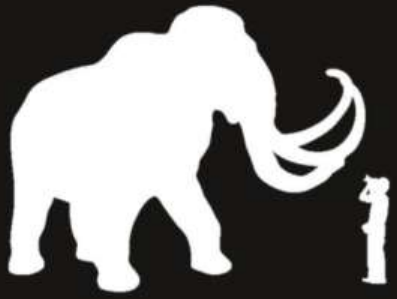
"Reverse engineering DNA could be done now by snipping out bits and inserting bits, but who is to provide the pattern for DNA of any dinosaur? I can see no way we can provide even a faint guess at their genome," he says. "Why bother? And, if we could, surely we have more important purposes to which to put the technology – like engineering out disease or engineering in food productivity."

Predictably, Shapiro is more hopeful. "We now know the complete genome sequences of more than 50 species of birds, as well as alligators and crocodiles," she says. "Using these data, we can reconstruct, using a computer and models of how genomes change over time, what the most likely sequence of the common ancestor of birds was. We might then go into the genome sequence of a living bird and change it so that it looks like this common ancestor. For now, this is a thought experiment, of course."

While such a technique is not possible today, the rate of advances in gene technology mean it may be conceivable in 50 years. And, considering our love affair with dinosaurs, how could we resist?

CRISPR enzyme (green and red) binding to DNA and preparing to snip out the faulty part

The last mammoth population lived on Wrangel Island, 140km off the coast of northeast Siberia, and died out around 4,000 years ago



HOW TO REAR DINOSAURS TO MATURITY

Even with dinosaur DNA, the route to a fully-grown animal is complex. "To work properly, DNA has to be packaged," explains palaeontologist Dr Henry Gee. "Many parts of DNA are coiled around protein complexes called histones. The degree to which DNA is wrapped around histones has a bearing on which genes are turned on during development and when.

Gee adds that much of DNA is modified chemically, as part of a pattern called the epigenome. This is also vital in development. "The most important thing, however, is the early maternal environment. The earliest stages in the development of an embryo depend on chemical factors left in the egg by the mother. Even having the right factors in the right places within the egg is important," explains Gee. "As we don't have fresh dinosaur eggs to work with, we'd have to use crocodile or bird eggs. Scientists know an awful lot about chicken eggs, so perhaps they'd start with those."

Luckily, not all dinosaurs were on the scale of Diplodocus – there were plenty of chicken-sized dinosaurs that we could experiment with before jumping straight to the big boys. When it comes to rearing, we would need to be aware of species requirements – just as with birds.

"We know that some dinosaurs behaved very like birds with respect to nesting and incubation," says Gee. "We also know that reproductively active female dinosaurs underwent secondary remodelling of their bones, associated with providing calcium for the eggshells and embryos. So, in some cases at least, birds and dinosaurs behaved very similarly. But dinosaurs were very diverse, and it is possible that they had a range of reproductive habits, from full-on parental care, to laying eggs in a nest or mound and forgetting all about them."

Not all dinosaur eggs were as big as this

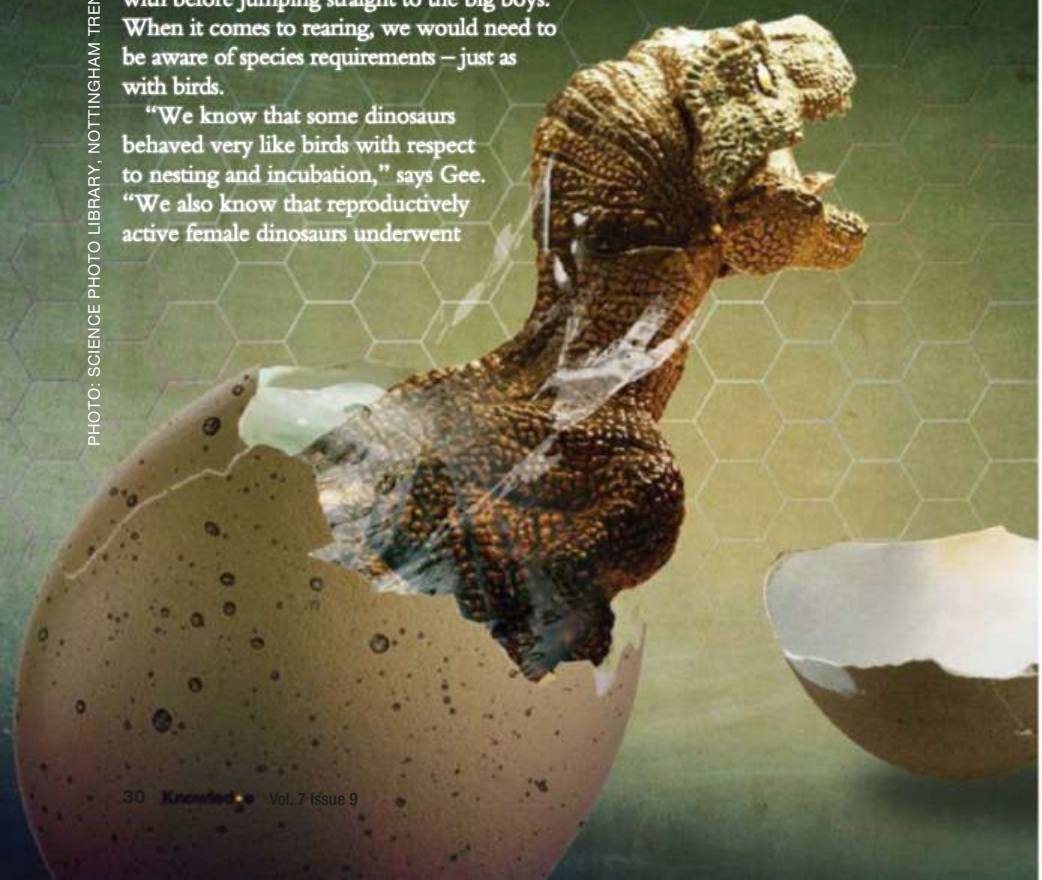


PHOTO: SCIENCE PHOTO LIBRARY, NOTTINGHAM TRENT UNIVERSITY ILLUSTRATOR: ANDY POTTS

HOW TO MANAGE THEM

The owners of a dinosaur reserve would need to keep their animals safe and happy, while giving visitors a chance to see them as close-up as possible. The European Association of Zoos and Aquaria (EAZA) produces a detailed file on the management of each major species called an EEP (European Endangered Species Programme), which would need to be extended to include dinosaurs.

The difficulties of handling large dinosaurs are likely to be surprisingly similar to those faced when looking after large mammals – a fully-grown male African elephant can weigh up to seven tonnes, a similar weight to a T. rex. Although a large, grazing sauropod like a Diplodocus could weigh up to three times as much, they would be far slower. They would therefore provide less of an issue for any barrier than a high-speed predator. In practice, it's likely that the dinosaurs could be kept in place by using traditional concrete and rock barriers.

Bob Lawrence, Head of Wildlife Development at West Midland Safari Park, points out that one vital aspect of keeping animals secure is understanding the social grouping of the particular species. For example, some tolerate a male hierarchy, but others only allow one mature male in

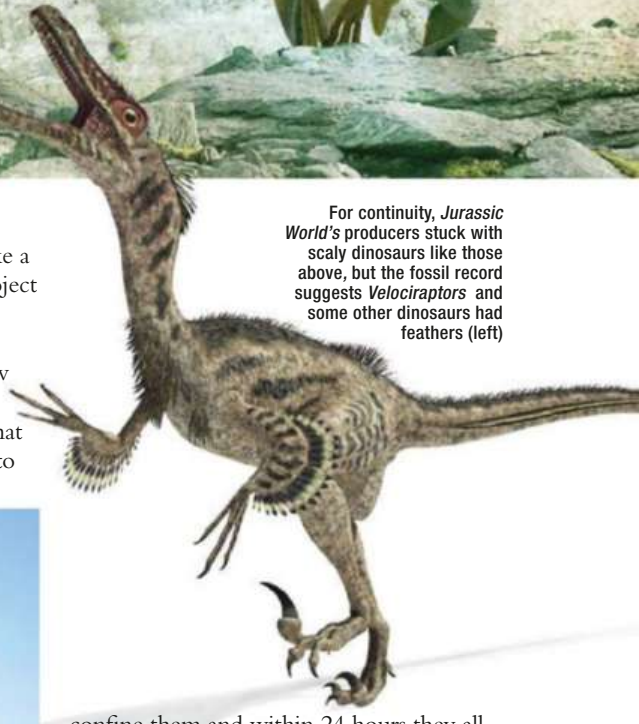
a group. The latter scenario would result in battles where the loser would attempt to flee and could try to charge out of the enclosure, putting the containment under stress. With our limited understanding of dinosaur social groupings, there would be an initial need for an environment where security was paramount to avoid escapes.

Elephants are often confined using electric fences, but Lawrence points out that not only are these potentially inhumane, but more intelligent species can find ways to disrupt them. Elephants have been known to short them out using tree branches and there is always the possibility of technical failure. Steel barriers or high walls would need to be capable of withstanding the impact of charging dinosaurs. When housing elephants, about 2.5m is the recommended minimum height for a barrier, but in the case of taller dinos, this would have to be increased appropriately.

For smaller predators like Velociraptors, Lawrence recommends the kind of fencing used for wolves, which typically involves a 45-degree inward overhang. This is essential when the animals can be good jumpers.

Lawrence recommends siting a dinosaur park in an old quarry, such as the disused chalk pits in Kent. These can have sides over 30 metres deep, keeping the animals safe from escape. Such a location can also make a very attractive visitor site, as the Eden Project in Cornwall has proved. It would also be much more secure than using an island to confine species when we don't know how well they'd cope with water. "We were caught out once when we didn't realise that wallabies could swim. We used an island to confine them and within 24 hours they all swam off," Lawrence explains.

According to Bob Lawrence, we must understand social groupings to keep animals safe and secure



For continuity, *Jurassic World's* producers stuck with scaly dinosaurs like those above, but the fossil record suggests *Velociraptors* and some other dinosaurs had feathers (left)

For smaller dinosaurs, existing bird enclosures would likely prove fine.

"One might have greater success with some of the smaller, feathered dinosaurs, no bigger than crows or pigeons, which could be kept in a large aviary," says Gee.

For a thylacine, the issues would be similar to those in breeding any large animal. "The same issues would need to be addressed, including optimising genetic diversity and acclimatisation to the attributes

FIVE FREEDOMS

Zookeepers refer to five freedoms of animals, which would inevitably be extended to dinosaurs. These are:

1. Freedom from hunger and thirst
Adequate, well-balanced and timed nutrition must be provided.

2. Freedom from discomfort
A suitable environment with shelter and appropriate materials allows animals to live as closely as possible to a natural environment.

3. Freedom from pain, injury and disease
Animals should not be put at risk by the enclosure and should have good access to veterinary medicine.

4. Freedom from fear and distress
These can be avoided by providing correct grouping and sex ratios, and including an appropriate mix of species. There should be a lack of unnecessary confinement and places to escape from view.

5. Freedom to behave normally
In old-fashioned zoo environments, animals would pace unnaturally. Instead, they should have somewhere to express their natural behaviour as closely as possible.

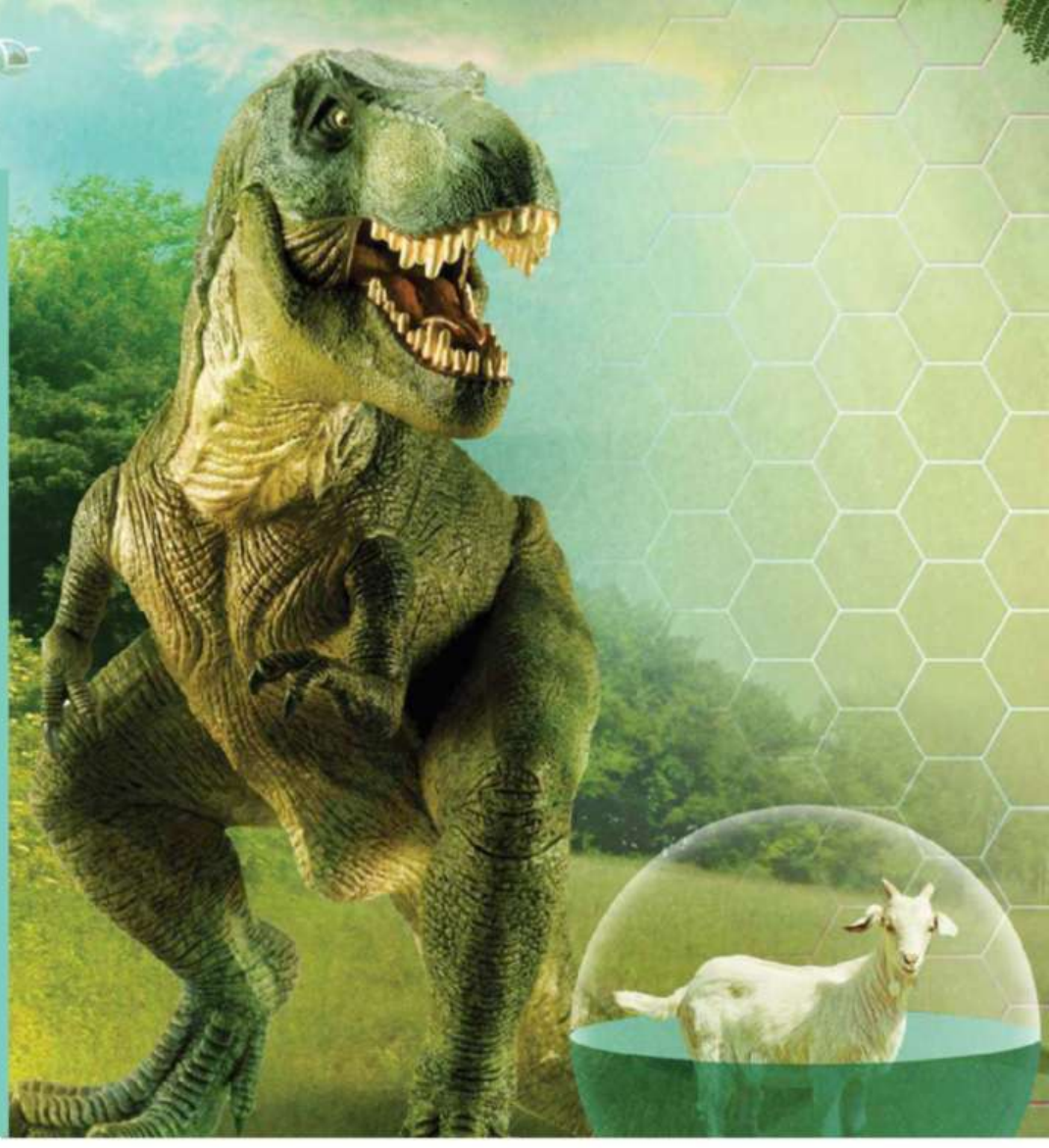


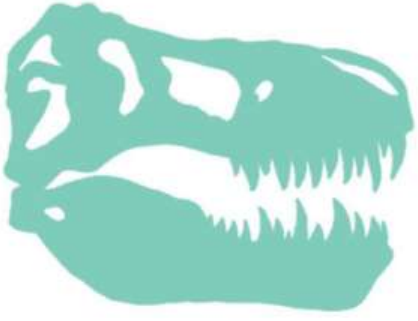
PHOTO: PRESS ASSOCIATION, JOHN D/CATHERINE T/ MACARTHUR FOUNDATION ILLUSTRATOR: ANDY POTTS

of potential release habitats," says Archer. "For some animals and plants, a parallel conservation strategy might involve enabling suitable species to become human companions. If this had been legal when thylacines were being kept as pets in Tasmania, it's depressingly clear that the thylacine would not be extinct today. There are lessons to be learned from this tragedy, based on the erroneous presumption that wildlife is always safest in the wild."

There is always going to be compromise, but good zoos and wildlife parks will have the animals' welfare at their heart. The trouble with dinosaurs is that so much would initially be a matter of guesswork.

Take the T. rex. For years this dinosaur with immensely powerful jaws was considered a straightforward predator. Yet some palaeontologists suggest that, like a hyena, it was almost entirely a scavenger and primarily lived off the kills of others. There is evidence to support both theories, which is typical of the uncertainty we face.

Equally, there is some evidence that T. rex indulged in cannibalism. After years of hard work, it would hardly be great news if one specimen ate the rest. Similarly, although it has been suggested that dinosaurs were less susceptible to disease than mammals, this is based on inference from the fossil record, which is patchy in the extreme.



Computer modelling suggests that an adult *T. rex* could bite with a force of over five tonnes

With very large animals, there is also the problem of getting enough food into the enclosure at a time. A T. rex would probably need 40,000 calories a day, equivalent to eating a large goat. There's no reason why it couldn't cope with modern meat, though if it proved to be primarily a scavenger it would be more likely to be fed with, say, a cow carcass on a less frequent basis. Any sensible T. rex facility would have a failsafe mechanism for delivering food without having to risk physically entering the enclosure.

A large herbivore like Diplodocus probably had a diet of ferns and soft leaves – there would be considerably more concern about finding appropriate diets (think, for example, how fussy a panda is in requiring bamboo shoots). But whatever the exact plant life involved, an animal with this bulk would need large quantities of vegetation – perhaps half a tonne per day. In this case, the supply might be challenging, but at least the enclosure can be entered with less risk.

Currently, we know so little for sure. This is why, even if they weren't perfect, the idea of creating dinosaur hybrids could help palaeontologists get a better picture of Jurassic and Cretaceous life.

WHO WOULD RUN THE PARK?

While none of these individuals is involved in creating a dinosaur attraction, they're exactly the kind of people such a venture would need…

THE ANCIENT DNA EXPERT
DR BETH SHAPIRO
Recreating dinosaurs would mean finding out as much as we could about their DNA and reverse engineering what we couldn't find. An expert in ancient DNA is an essential cast member, and Shapiro already has a project working on a form of reverse engineering.

THE DE-EXTINCTION EXPERT
PROF MICHAEL ARCHER
Archer and a small number of individuals are looking at the practicalities of producing a living specimen of an extinct creature. The work currently focuses on recently extinct mammals, but for the park that would have to be extended much further.

THE PALAEONTOLOGIST
PROF MICHAEL BENTON
We can't get anywhere without an expert in dinosaurs. These scientists can help us discover remnants and will increase our understanding as much as possible. They can teach us about the lifecycles of the animals to give us the best chance of successfully rearing them.

THE BACKER
CLIVE PALMER
This eccentric Australian mining billionaire is exactly the kind of backer that would be essential to get an ambitious project like this off the ground, as it would require a huge amount of funding. According to the Australian press, Mr Palmer has already expressed an interest in cloning dinosaurs.

THE SHOWMAN
SIR RICHARD BRANSON
There is no doubt that the Virgin owner is an ultimate showman and he already owns a private game reserve, Ulusaba in South Africa, adjoining the Kruger National Park. Sir Richard's ebullient enthusiasm and media access make him an ideal candidate for launching a dinosaur park.

WHERE TO PUT THE PARK AND HOW TO ENGINEER A HABITAT

We tend to lump together dinosaurs as a single group of animals – but they lived over a huge time period from the Jurassic (200-145 million years ago) when massive herbivores like *Diplodocus* were common, through to the late Cretaceous (100-66 million years ago), when the likes of *T. rex* and *Velociraptor* thrived. Not surprisingly, the habitats varied. But generally the need would be for a warm, humid environment with plenty of coniferous trees and fern plantations.

However, it isn't always essential to match a habitat to an animal. With suitable winter protection, African animals can survive comfortably in British safari parks. And it may be that dinosaurs would be equally adaptable, although this is something that would require experiments with living animals to determine. With this in mind, the first park would require highly controlled and large-scale environments. As such, it wouldn't really matter where in the world the park was situated. The driving factor would more likely be the source of funding.

The key to the adaptability of the animals would be whether they resembled warm-blooded birds, or cold-blooded crocodiles. A fully warm-blooded organism can cope with much wider ranges of climate, whereas cold-blooded animals require a more controlled temperature range to thrive. Although we have moved away from the idea that dinosaurs were cold-blooded, we still don't know for sure whether something like a *T. rex* had a full-scale warm-blooded metabolism or something in between the two, leaving it more susceptible to the cold. The only way we can find out for definite is by experiment.

Modern birds are descended from a group of dinos called theropods

VISITOR EXPERIENCE

Dinosurs would be so valuable that the visitor experience would come second to security. Good walls, designed to look like natural structures, with viewing points and ports would give the best combination of safety and access. In a future Eden Project-style environment, there could be virtual robotic tours of the enclosures and the ability to fly over the the top in a totally transparent vehicle.

We know already from dinosaur exhibitions that there will be plenty of spinoffs. It's

Microbiologist Raul Cano isolated ancient yeast to make Fossil Fuels beer

unlikely that the restaurant would serve actual mammoth or dinosaur burgers, but it would be possible to use the same technology that produced a £200,000 lab-grown burger to grow mammoth and dinosaur meat. Bear in mind that in less than two years, the price of making a lab burger has dropped to under £10. To accompany their meal, visitors might like a glass of the Fossil Fuels Brewing Company's beer, claimed to be made using a yeast strain dating back 45 million years.

No doubt dinosaur toys making realistic sounds would be popular – but as yet, we have little idea of the noises that dinosaurs made. There has been speculation that strange bony head crests on some duck-billed dinosaurs were used to create resonant cries, but most dinosaur noises featured in movies and documentaries are simply reused from existing animals.

Palaeontologist Phil Senter has even suggested that dinosaurs may not have had cries at all. This is because their two living descendants, the birds and crocodilians, have totally different sound-making mechanisms from each other, suggesting their common ancestor may have had neither. But after the noise of the *Velociraptor claws* on the floor in *Jurassic Park* gave us nightmares, we'll be thinking twice about a dino attraction…

We could safely explore a dinosaur attraction in transparent pods, like the ones featured in *Jurassic World*

BRIAN CLEGG is a science writer whose most recent book is *Science For Life*

THE ROBOTIC RACE TO THE MOON

Rovers could be roaming the lunar soil this year, says **Rob Banino**, but who's in pole position?

PHOTO: XPRIZE PRESS OFFICE

The first space race began back in 1955, when eminent Russian physicist Leonid Sedov revealed the USSR's intention to send a probe into space four days after the US announced plans to launch a satellite. Sixty years later and we are approaching the closing stages of another space race: the Google Lunar XPRIZE (GLXP).

The finish line is the same, the Moon, but the competitors are different. Rather than nations with competing ideologies, they're private companies seeking to commercialise space. And all they have to do to win the US$20m grand prize is be the first to have a non-government-funded vehicle drive on the Moon's surface.

"The GLXP is asking teams to accomplish a feat that has never been achieved: land a private craft on the lunar surface, then have it travel at least 500 metres and transmit high-definition video back to Earth," says GLXP's president Robert Weiss. And they have until 31 December 2016 to do it.

More than 30 teams signed up to GLXP when it launched in 2007. Only 18 are still in the running, and of these, five are clear frontrunners. In January this year these teams shared Milestone Prize money totalling US$5m (£3.2m) for demonstrating viable technology across three categories: landing, mobility and imaging.

America's Astrobotic team was the only one to win prizes in each of the categories, thanks to the progress made with its Griffin lander and Andy rover.

PART-TIME SCIENTISTS

BERLIN, GERMANY

MILESTONE PRIZE MOBILITY
SIZE 90 x 75 x 60cm
WEIGHT 40kg

This team is comprised of scientists from all over Europe collaborating via the internet. The Part-Time Scientists team is building a four-wheeled, solar-powered rover called Asimov, which they tested on Tenerife's Mount Tiede volcano in December 2014 due to its similarity to the lunar surface. Their aim is to have Asimov travel to the Apollo 17 landing site and take pictures.

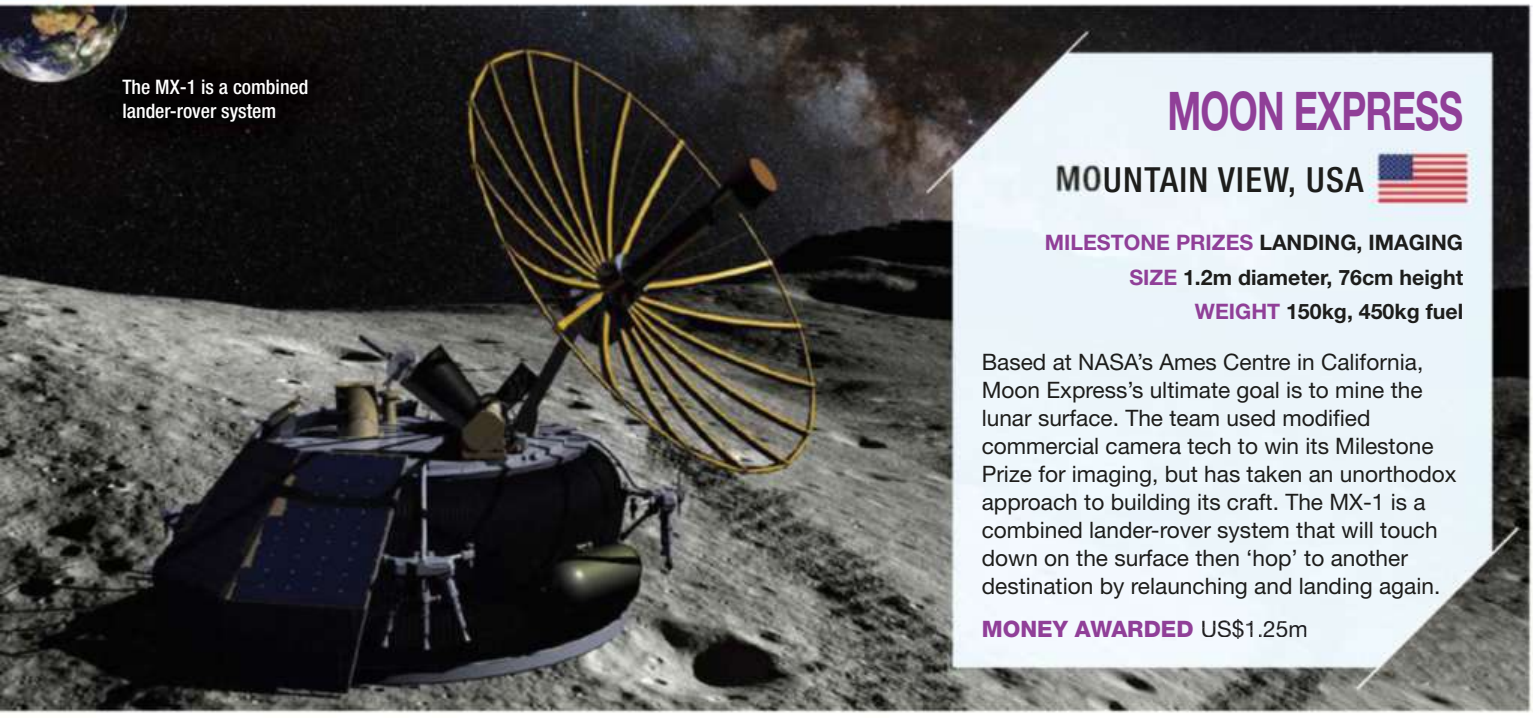
MONEY AWARDED US$500,000

Astrobotic proposes to carry at least four other competitor rovers to the Moon in Griffin, which is set to launch aboard a SpaceX Falcon 9 rocket in the second half of next year.

The sole Japanese entry, Hakuto, is signed up as Astrobotic's first passenger. Hakuto won a US$500,000 mobility Milestone Prize for its paired rovers Moonraker and Tetris.

"We are planning to explore a hole on the Moon that's thought to be a lava tube," says Hakuto's Kyoko Yonezawa. "A lava tube would be a perfect place to build a lunar base, since it would be protected by a thick layer of rock from intense radiation and extreme temperatures. Tetris, connected by a tether to Moonraker, will be lowered into the hole to explore the lava tube."

The potential fortunes to be made from payload delivery systems, colonisation and lunar mining are what all the GLXP competitors ultimately aspire to, but the first challenge they have to overcome is funding. Although the prize money for the winner and runners-up totals US$30m, it's just a drop in the ocean compared to how much is needed to turn these projects into viable businesses. That's the real challenge behind the GLXP – to make lunar exploration affordable for organisations other than government agencies, so we don't have to wait another 45 years before our next visit to the Moon.



The MX-1 is a combined lander-rover system

MOON EXPRESS

MOUNTAIN VIEW, USA

MILESTONE PRIZES LANDING, IMAGING
SIZE 1.2m diameter, 76cm height
WEIGHT 150kg, 450kg fuel

Based at NASA's Ames Centre in California, Moon Express's ultimate goal is to mine the lunar surface. The team used modified commercial camera tech to win its Milestone Prize for imaging, but has taken an unorthodox approach to building its craft. The MX-1 is a combined lander-rover system that will touch down on the surface then 'hop' to another destination by relaunching and landing again.

MONEY AWARDED US$1.25m

ASTROBOTIC

PITTSBURGH, USA

MILESTONE PRIZES LANDING, MOBILITY, IMAGING
SIZE Griffin 4.5m diameter, 1.6m height; Andy 100 x 100 x 90cm
WEIGHT Griffin 535kg, 1,685kg fuel; Andy 33kg

Astrobotic's long-term goal is to use its Griffin lander as a delivery system for customers to send equipment to the Moon (they've already signed up Hakuto's rovers as its first 'passengers'). The team has close ties to Carnegie Mellon University, which is a world leader in robotics, and has developed the Andy rover to be able to travel at 15cm per second and climb 15° slopes.

MONEY AWARDED US$1.75m

Astrobotic's Griffin lander will take equipment to the Moon for other customers

ROBOTS TO SCALE

The XPRIZE competitors are packing some serious technology inside their Moon exploration systems. But how do they measure up to one another?

Hakuto Moonraker rover

Team Indus rover

Part-Time Scientists Asimov rover

PHOTO: XPRIZE PRESS OFFICE X4

TEAM INDUS

NEW DELHI, INDIA

MILESTONE PRIZE LANDING
SIZE Rover 40 x 50 x 60cm
WEIGHT Rover 12kg

Team Indus plans to use a Polar Satellite Launch Vehicle rocket belonging to the India Space Research Organisation to take its HHK1 lander and two solar-powered rovers into space. One of the rovers is tasked with winning the $20m grand prize, but Team Indus is looking to set range and endurance records with its second vehicle.

MONEY AWARDED US$1m

Two rovers are being sent to the Moon by Team Indus, with hopes of winning the grand prize

HAKUTO

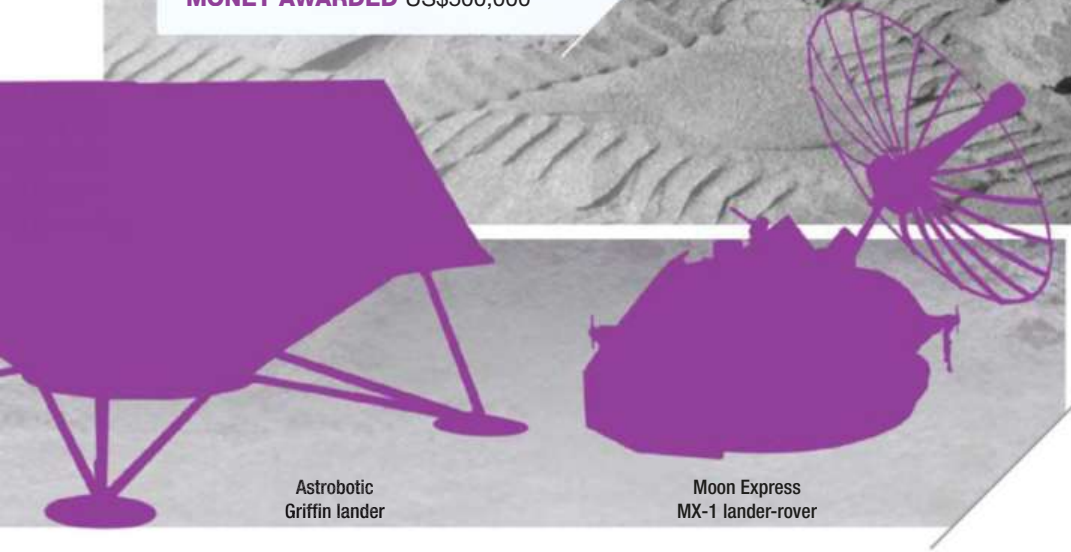
TOKYO, JAPAN

MILESTONE PRIZE MOBILITY
SIZE Moonraker 48 x 60 x 54cm; Tetris 27 x 54 x 21cm
WEIGHT Moonraker 8kg; Tetris 2kg

The word 'Hakuto' comes from a Japanese folktale and means white rabbit – hence the ears on the team's logo. The team, based at Tohoku University, is using Astrobotic's lander to carry its Moonraker and Tetris rovers to the Moon where it hopes to win the range prize by using Tetris, its smaller rover, to explore a lava tube beneath the lunar surface.

MONEY AWARDED US$500,000

Moonraker, shown here, is the larger of the two rovers. It will lower the Tetris rover into lava tubes



Astrobotic Griffin lander

Moon Express MX-1 lander-rover

ROB BANINO is a science and technology journalist. He also writes for our sister science title *BBC Sky At Night Magazin*

WHEN THE WELL

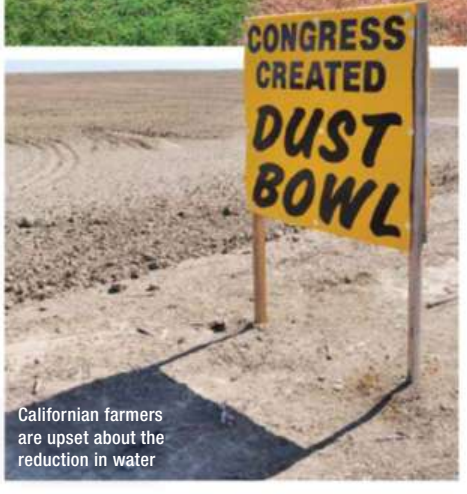
RUNS DRY

After a fourth consecutive year of drought, California's reservoirs are running dry. Hayley Birch looks at the technology that could help solve the crisis, and put an end to drought around the world

The website of LawnLift proclaims that, "It's like a facelift for your lawn!" The US company offers a quick fix for crispy-looking Californian lawns by painting them green. Since the onset of drought in the state, spray painting lawns has become big business. More than three years on, with the drought showing no sign of ending, the Californian water board has adopted emergency regulations that make watering your garden more than twice a week a punishable offence. At the beginning of April, state governor Jerry Brown announced restrictions that will force water suppliers to reduce their output by a quarter, by February 2016.

It's not just the lawns that are parched. Levels at lakes and reservoirs have dropped to historic lows and farmers are leaving fields unplanted because there isn't enough water to irrigate their crops. Like anyone who lives in California, Brian Luenow, who works in water pollution monitoring in San Francisco and runs a website covering water issues called HydrateLife, sees a lot of the impact. "Along Highway 5, the big highway that runs the length of California, you see empty fields, you see dead trees. You see a lot of signs put up by farmers, because some of them aren't getting water from the government this year, so there are a lot of people upset by that."

Grass painting is now big business in California



Californian farmers are upset about the reduction in water

Where's the water?

Water scarcity is a problem that affects countries in every part of the world, either because they experience periods of extremely dry weather, or because populations are increasing rapidly, or because the water isn't distributed properly – or all of the above. For decades, the amount of water we use globally has been growing faster than the population, meaning that within 10 years we could be living in a world where two-thirds of people face 'water stress'. This is a situation where the demand for water is greater than the supply. African countries are some of the most water stressed, but even some European countries and US states are facing serious challenges in supplying enough. The world's well is running dry.

PHOTO: ISTOCK, GETTY, ALAMY

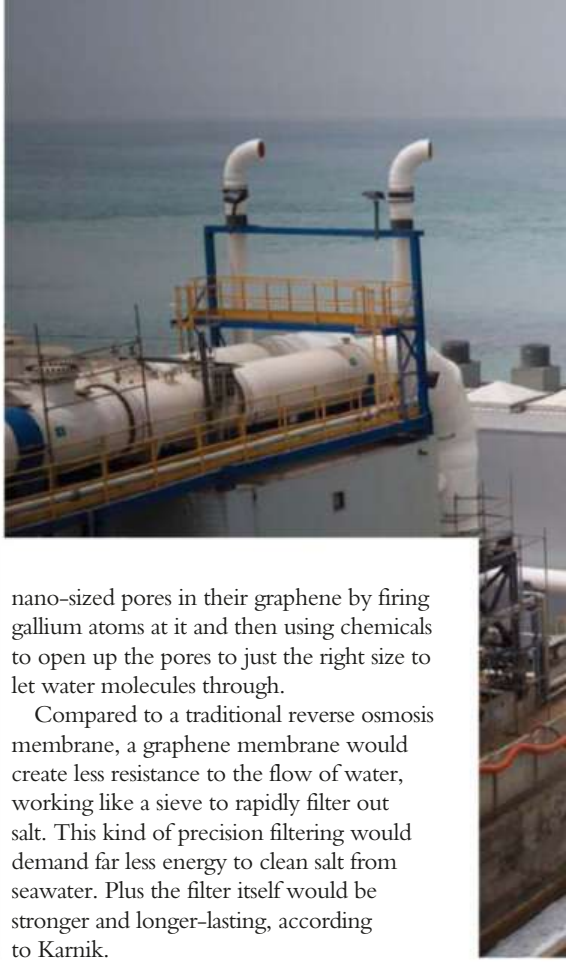
In arid countries like Israel, which gets practically no rain between May and September, conserving water is a way of life. In contrast, Californians don't think about it as much. "They're used to just turning on the taps and having water," says Luenow. Over time, education might be able to change the West's attitude to water, but that will only go so far. Luckily, solutions to our global water shortages could be on the horizon.

Across the divide

Israel gets 40 per cent of its water from the sea through desalination, which involves removing salt from seawater. This is a solution to which the Golden State is now turning. One of the most widely used desalination technologies – the reverse osmosis membrane – was invented back in the 1950s. The trouble is, the process uses a lot of energy. But today, researchers in Cambridge, Massachusetts think they may have found a way to make it meet the demands of the modern world.

Reverse osmosis uses high pressure to force seawater through a membrane. The salt can't get through and is left behind. At the Massachussetts Institute of Technology, Dr Rohit Karnik's team has been working on a reverse osmosis membrane made from graphene, a carbon 'wonder' material that's atomically thin. In a study published last year, they showed they could make trillions of nano-sized pores in their graphene by firing gallium atoms at it and then using chemicals to open up the pores to just the right size to let water molecules through.

> "The public need to be made more aware of what's happening with water"
>
> Brian Luenow, founder of the HydrateLife website



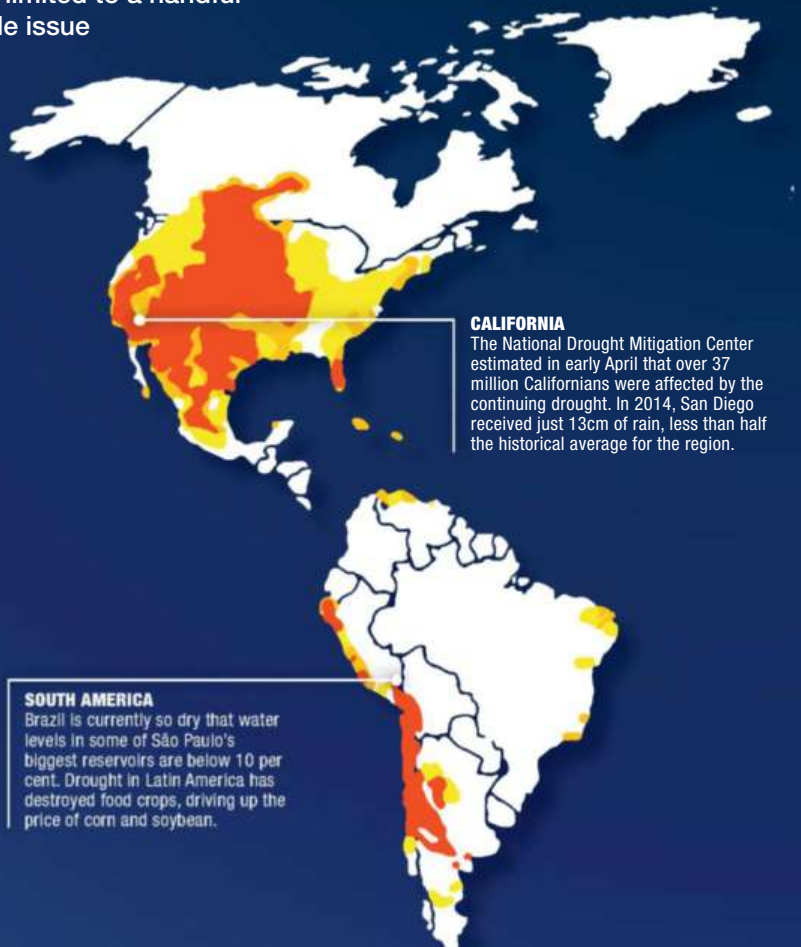
Compared to a traditional reverse osmosis membrane, a graphene membrane would create less resistance to the flow of water, working like a sieve to rapidly filter out salt. This kind of precision filtering would demand far less energy to clean salt from seawater. Plus the filter itself would be stronger and longer-lasting, according to Karnik.

WATER STRESS

The shortage of water is not limited to a handful of countries – it's a worldwide issue

70% of the world's accessible freshwater is sucked up by agriculture

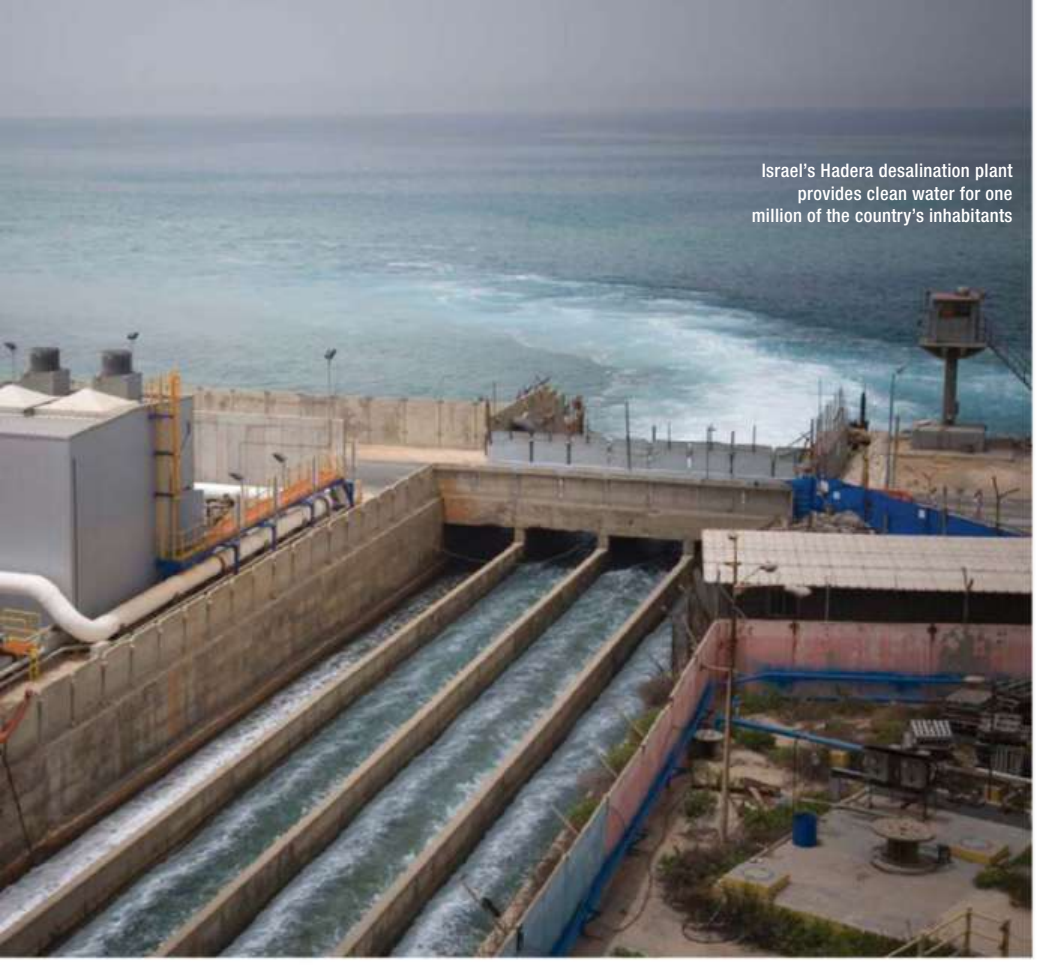
783 million people do not have access to clean water



CALIFORNIA
The National Drought Mitigation Center estimated in early April that over 37 million Californians were affected by the continuing drought. In 2014, San Diego received just 13cm of rain, less than half the historical average for the region.

SOUTH AMERICA
Brazil is currently so dry that water levels in some of São Paulo's biggest reservoirs are below 10 per cent. Drought in Latin America has destroyed food crops, driving up the price of corn and soybean.

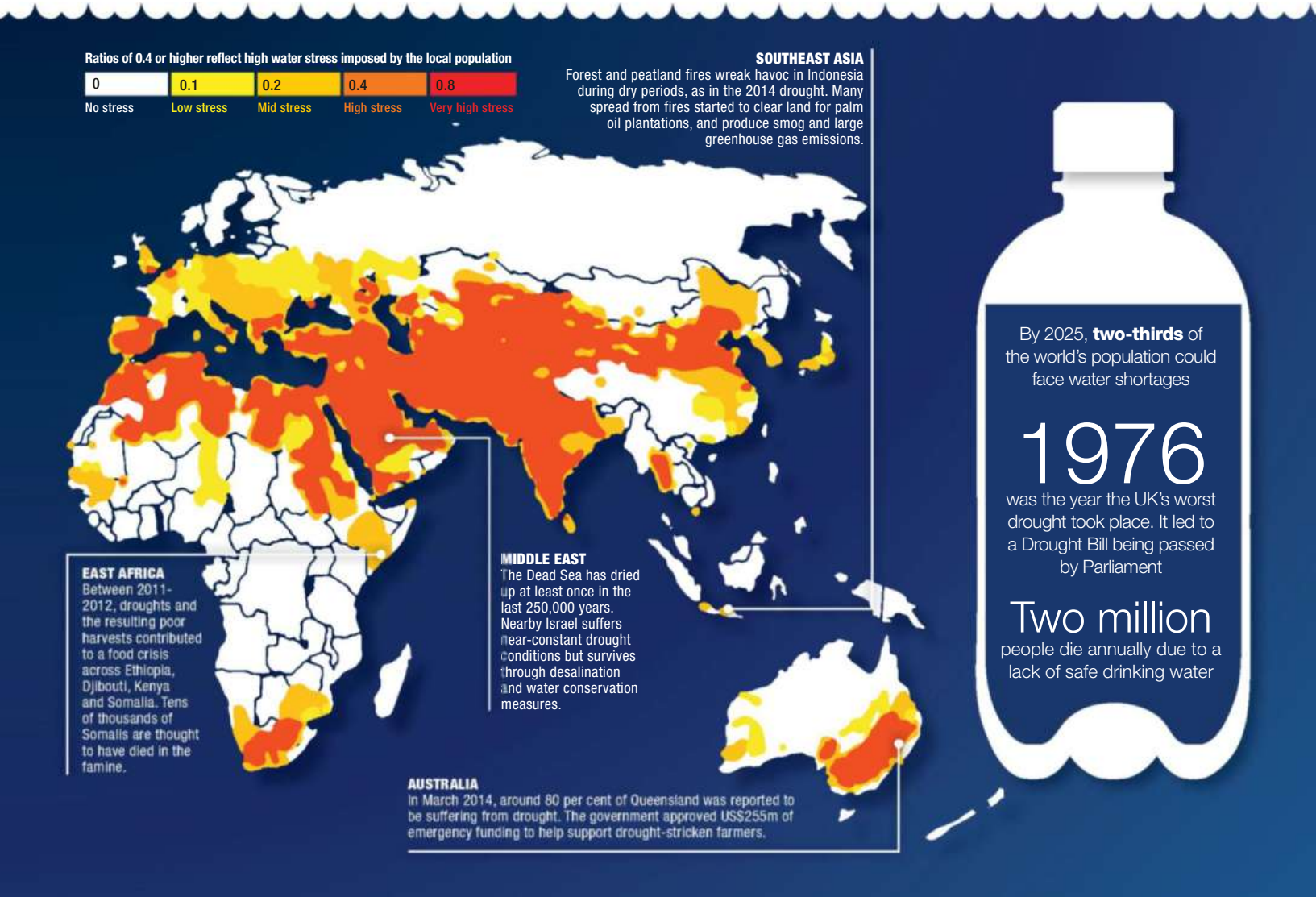
PHOTO: PRESS ASSOCIATION



Israel's Hadera desalination plant provides clean water for one million of the country's inhabitants

Across California, desalination projects that were built and then deserted or downscaled after previous droughts are being revitalised, although they won't use graphene filters just yet. Higher performance membranes could eventually mean more efficient desalination, but what about the cost of these filters? Graphene has a reputation for being expensive to make, but Karnik thinks the cost of production will come down as it gets adopted for applications such as flexible electronics. "Some companies are already making it roll-to-roll," he notes.

On the other side of the Pacific, city state Singapore is known for its innovative water practices. It uses membrane filtering technology to get as much as a quarter of its water from desalination. But it also uses reverse osmosis for another reason: to turn waste water into drinking water at its NEWater purification plants. In the US, this reclamation process is often branded 'toilet-to-tap' and it's a tricky subject. Luenow says the government needs to make a bigger effort to teach people about these kinds of new technologies and how desperately they're needed. "There have been a lot of studies on



it and the consensus is that what's coming out at the outlet is perfectly fine to drink. I think the public need to be made more aware of the bigger picture of what's happening with water, because if people don't realise how bad this drought is, they're not really going to see the need for this kind of thing."

Using our waste and the seas to provide clean water could help Californians maintain their way of life during the droughts, but ultimately it won't be much help to those that need relief most. Developing countries, particularly those that are landlocked, will have to look for more radical solutions.

Drought defence

One answer might be genetically modified crops that cope better in dry conditions. For desperate farmers, planting crops that are specially engineered to resist drought could be one way to prevent fields from falling fallow. Plant scientist Sean Cutler is working on switching on genetically engineered drought tolerance using chemicals already available to farmers. Based at the University of California, Riverside, Cutler's own institution has an action plan for water conservation and there have been local quarrels over sprinkler usage, with one city councillor complaining he'd have to move house if restrictions wouldn't allow him to water all his shrubs.

The approach Cutler's team described in Nature earlier this year could be applied to many different crops, but they tested it in a model species called Arabidopsis, which is related to cabbages. They'd already tracked down the right receptor – a molecular switch in the plant that triggers water storage, including by closing pores in the leaves that let water vapour escape. In the new study, they edited the plant DNA that encoded that receptor so it could be activated by a fungicide usually used for crop protection. "It's the first time anyone's ever taken a plant and made it so that an agrochemical can turn on a pathway that it wasn't designed to regulate," says Cutler. "There are other receptors in the plant that could be activated chemically and there's no reason why you couldn't apply the strategy that we outline to those." The idea is that, eventually, it might be possible to spray a field of crops with one chemical and have it switch on a whole raft of different drought defence mechanisms.

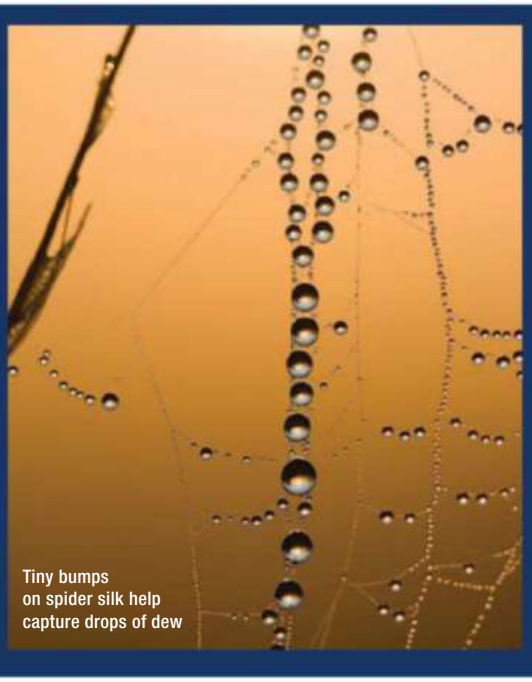
In the US, as in Europe, there is still some resistance to genetically modified organisms (GMOs). But as Cutler explains, unless the crops have new genes added to them, they

Sean Cutler believes a particular fungicide could 'switch on' a plant's drought defence mechanisms

HOW SPIDER SILK COLLECTS WATER

Why do spider webs sparkle like diamonds on a dewy morning? It's all down to their intriguing structure…

Many water-hoarding materials exist in nature, such as the leaves of certain plants and the backs of desert beetles. Incredibly, spider silk also has a structure that is perfectly adapted to water collection. In 2010, a team of Chinese researchers published a paper in the journal *Nature* revealing important details of this structure. The scientists showed that when spider silk gets wet, rough-textured bumps start to form along the otherwise smooth fibre of the silk. The difference in the texture of the silk creates differences in pressure and energy that drive water towards the bumps, enhancing the silk's water-collecting ability. This is why we see water clinging to a spider's web in distinct droplets, with the bumps – or what the scientists called 'spindle knots' – acting as collection sites. The challenge now is to create cheap, bio-inspired materials that mimic the structure of natural spider silk to harvest moisture from fog in dry regions. The materials, which are designed by Prof Yongmei Zheng and her team at Beihang University, are made by dip-coating a smooth artificial fibre in a polymer fluid that breaks up and dries to form the bumps that are so crucial to the structure.



Tiny bumps on spider silk help capture drops of dew

PHOTO: UCR STRATEGIC COMMUNICATIONS, NEIL HALL X3, FLPA

South America has seen a great deal of success with collecting fog using mesh-like nets, such as these in the Atacama Desert

are not considered to be genetically modified in the US. "So there are probably [genetic] strategies we could exploit without invoking the GMO issue," he says.

Drought-tolerant crops are a solution that could be employed in most places in the world, particularly in inland regions where desalination isn't such a straightforward option for a water supply. Some African nations using more traditional crop breeding approaches have already been helping growers to make the best of the dry conditions. In Chad, for example, subsistence farmers started sowing drought-tolerant sorghum seeds in the 1990s, leading to increases in yields of the grain by up to half.

Water from thin air

Reducing the amount of water you use is one thing, but coming up with new water sources in places where there is very little is quite another. One quirky approach being tested in communities all over the world is fog collection. Everywhere from Chile to Oman, researchers and local people have been stringing up nets to soak up water from thin air.

These nets are reminiscent of giant spider webs capturing droplets of dew. In fact, at Beihang University in Beijing, China, Prof Yongmei Zheng and her team are taking inspiration from spider webs to make better fog-collecting materials. After finding that water collects on tiny bumps in spider silk, they mimicked the bumpy structure with artificial, nylon-like materials and worked out a way to spin them into long threads. "Many fog-catching projects around the world seem to use the same materials that have been used for a long time," says Zheng. "The bioinspired fibres have a better ability to collect water than the normal fibres." She says they are developing experiments to test the fibres outside the lab and hope to set up projects in foggy regions elsewhere in the world.

> "Bioinspired fibres have a better ability to collect water than the normal fibres"
>
> Prof Yongmei Zheng, Beihang University

Back in California, Luenow is considering building a fog-catcher at home, although he hasn't got round to it just yet. Perhaps artificial cobwebs won't solve all of California's water problems, but then it's unlikely any single solution will. In one Guatemalan project utilising 30 fog-catchers, local families in Tojquia collected a total of around 6,000 litres a day. That's enough for about 3.5 Californians, based on 2011 figures, though at that point more than half of daily water consumption related to outdoor uses such as landscaped gardens.

Luenow worries that people still aren't waking up to the issue of water scarcity, even after years of drought. "Most people have never even thought about the fact that water could become so scarce," he says. He suggests everyone has to take a little bit more responsibility – from the politicians, to farmers and bottled water companies pumping water out of the ground, and residents who care too much about having a pretty garden and not enough about having sufficient water to drink. We need to work together before Earth is no longer the Blue Planet…■

HAYLEY BIRCH is a science writer and author of *50 Chemistry Ideas You Really Need to Know, due out in 2015*

Having located a grub in dead wood, an aye-aye speedily chews a hole and winkles out the juicy morsel with its elongated middle finger

finger food

Nick Garbutt reports on new efforts to unravel the ecology of Madagascar's aye-aye, the lemur that's among Earth's most mysterious mammals

When I was a child in the mid-1970s I avidly collected WWF World Wildlife Collection cards from Shell garages. There were 16 in the set, so it took me a while to get them all, and the species I coveted the most was on Card No. 1: the aye-aye.

I remember few details about the 3D card itself, other than it said that there were fewer than 50 aye-ayes remaining in the remote forests of Madagascar. In 1966 and 1967 the Malagasy government had translocated nine animals (four males and five females) from capture sites on the mainland to the offshore island of Nosy Mangabe in the north-east, in what was thought to be a last-ditch attempt to save the species. Over the subsequent years these aye-ayes thrived, but on the mainland they were still believed to be restricted to tiny pockets of lowland rainforest in the north-east, and very close to extinction.

That perception continued for another two decades, until in 1990 Durrell Wildlife Conservation Trust (DWCT; then Jersey Wildlife Preservation Trust) organised a rescue mission to collect animals and begin a captive-breeding programme at Durrell Wildlife Park (formerly Jersey Zoo). The story of the expedition was famously recounted by Gerald Durrell in his last book – The Aye-aye and I: A Rescue Mission in Madagascar.

At the time of the expedition I was working on the neighbouring island of Mauritius with another Durrell project to help the endangered Mauritius kestrel, and we naturally received periodic progress reports from Madagascar. Not surprisingly the task proved to be very challenging. "We were expecting aye-ayes to be elusive, but not nearly impossible to find," says Lee Durrell, Gerald's widow and honorary

PHOTOS BY NICK GARBUTT

director of DWCT. "On his first casual night recce one of the senior expedition team saw four or five, gathered for a noisy mating session, but never again were they seen in such numbers. We searched for four weeks, day and night, but with no luck. Finally we were persuaded to host a ceremony in which the local elder, aided by rum and silver, called upon the village ancestors to bless our undertaking. Within a few days six animals had been caught!"

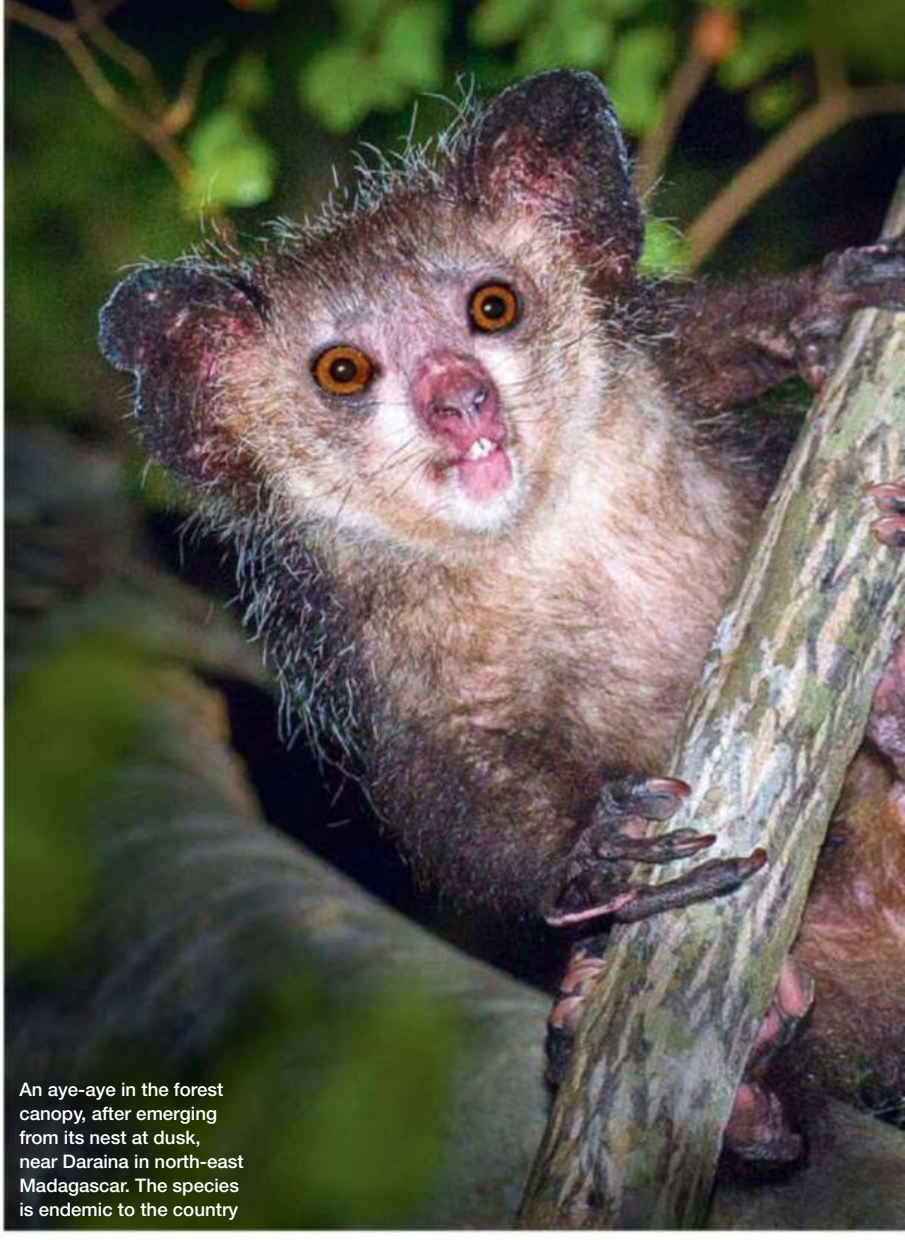
These aye-ayes have done well in captivity and the breeding initiative at DWCT has proved very successful (see, "Aye-ayes in captivity"). Indeed two of the original six animals are still alive today, 25 years after their capture.

Peculiar primate

Since its discovery and description in 1788, the aye-aye Daubentonia madagascariensis has been the subject of considerable debate and confusion. The animal was first classified as a squirrel-like rodent on the basis of its appearance. The species measures 74–90cm from nose to tail tip, with the tail making up more than half its length, and weighs roughly 2–2.5kg. It was only some 100 years later that it was finally accepted as a primate and lemur.

Indeed genetic analysis indicates that the aye-aye, along with all of the other lemurs, evolved from the same colonising ancestor primate, which rafted onto Madagascar about 55–60 million years ago. There is no question that the aye-aye is the most unusual and distinct offshoot of the lemur evolutionary tree, and it is placed on its own in the family Daubentoniidae. A second species, now extinct, once occurred in the dry regions of south-west Madagascar: the giant aye-aye D. robusta.

The aye-aye combines a peculiar amalgamation of morphological features and behavioural traits that set it apart. As with rodents, the front teeth (incisors) grow continuously throughout its life. Its ears are massive, mobile and leathery, resembling those of a large bat. Its extraordinary hands have



An aye-aye in the forest canopy, after emerging from its nest at dusk, near Daraina in north-east Madagascar. The species is endemic to the country

GRUBBING ABOUT HOW THE AYE-AYE FEEDS

1 Tap-scanning
In this hunting technique, also known as 'percussive foraging', the aye-aye uses its bony middle finger to repeatedly tap the surface of a rotten tree trunk or branch. The animal's extremely sensitive touch and large ears enable it to echolocate wood-boring grubs, a prey item rich in nutrients.

2 Chewing
The larvae live in tunnels and cavities that are 1–3cm beneath the surface. Once a grub is found, the aye-aye's chisel-like teeth make light work of the dead wood and a hole is quickly created. The speed is no surprise considering the species is able to gnaw through concrete.

3 Gouging
Finally the aye-aye uses the same middle finger to fish out the insects. The digit is normally cooler than the ambient body temperature, but during tapping its temperature increases by several degrees Celsius, suggesting greater blood flow and therefore sensitivity.

clawed fingers and a skeletal middle digit, and its mammary glands are low on the torso, between the hind legs. Add widely spaced, piercing orange eyes, a coarse, shaggy black coat and a long, bushy tail, and the overall effect is something resembling an electrocuted witch's cat with gremlin-like features.

Solving the puzzle

Aye-ayes are strictly nocturnal, mainly black, prefer to spend a lot of time high in the canopy, occur at low densities and occupy very large home ranges. So it is not surprising that there have been few successful wild studies. Eleanor Sterling from the American Museum of Natural History carried out some of the first ground-breaking investigations in the 1980s, and her studies still underpin much of our knowledge of the species in the wild.

"I spent two years on Nosy Mangabe, following aye-ayes throughout the night," she says. "During the day they sleep high in the canopy in nests made from interwoven twigs and fresh and dead leaves. Nests may be occupied for several days, but there is high turnover and different individuals often use the same nest on different occasions."

Aye-ayes have been regarded as solitary, only coming together when breeding, but Sterling's findings suggest otherwise. "They actually interact quite a lot outside the mating period. Animals come together in 'tandem foraging', often occupying adjacent or nearby trees while feeding. When one moves to another tree, they call quietly to one another and the second

The aye-aye resembles an electrocuted cat with gremlin-like features

TOP: aye-ayes build nests from twigs and leaves. Above: an aye-aye skull and skeletal hand showing the long digit adapted for 'tap-scanning'. LEFT: hungry aye-ayes chewed all of these holes

MADAGASCAR'S OTHER ODDITIES

There are no squirrels or woodpeckers on Madagascar and the aye-aye evolved to fill those niches. This phenomenon, when unrelated species such as lemurs, squirrels and woodpeckers evolve similar solutions to the same problem, is known as convergent evolution. Here are four other Madagascan examples.

1 The 'Toucan'

The helmet vanga is the closest Madagascar has to a toucan. Vangas are a bird family endemic (unique) to the island, with a bewildering variety of body sizes, bill types and plumage. Arguably the family's most spectacular member, the helmet vanga is found in rainforest in the north-east. It is an excellent hunter, spending long periods motionless before sallying out to pluck prey from branches or the leaf-litter.

2 The 'Cat'

Madagascar is missing many carnivores – it has no native cats, dogs, badgers, weasels, genets or otters, for example. The fosa, its largest carnivore, was wrongly described as a feline in 1833 due to the facial resemblance and semi-retractable claws. But it does hunt like an arboreal cat, being an agile climber. And it also has reversible ankle joints, so can descend trees by gripping with its rear feet behind its body, like the margay (a South American cat.)

3 The 'Dormouse'

The fat-tailed dwarf lemur is one of several tiny mouse and dwarf lemurs that enter periods of dormancy, much like dormice in temperate Europe and Asia. But whereas dormice hibernate in winter, these lemurs aestivate – a response to the dry season. To survive, the fat-tailed dwarf lemur builds up huge fat reserves in its swollen tail.

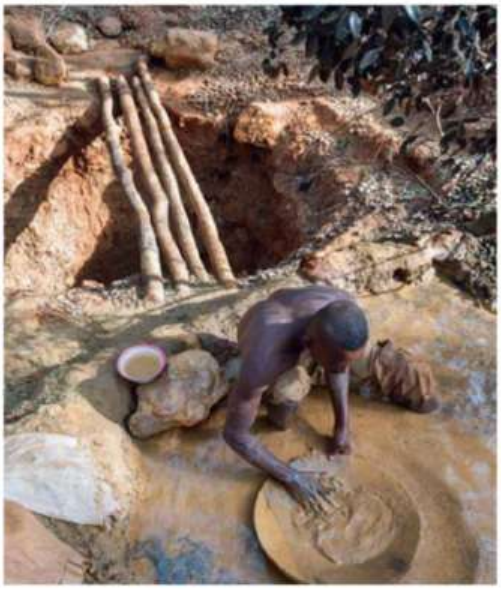
4 The 'Hedgehog'

Tenrecs are ancient mammals found primarily in Madagascar. Convergent evolution has driven the different species to resemble various small mammals from elsewhere in the world, such as shrews, moles and mice. The lesser hedgehog tenrec looks like a miniature hedgehog.

animal relocates nearby. They scent-mark too, telling others where they have been and possibly where to go. There may even be 'highways' along branches, routes that animals take and different animals follow on subsequent nights."

When they become receptive, females scent-mark and are highly vocal, mating with different partners during one oestrus cycle. Each copulation lasts about an hour – a lengthy period for a primate. This is probably the male's way of guarding against the advances of other suitors, but the ploy often fails, and the female begins calling again immediately to attract an alternative mate. Females begin breeding when three or four years old, and there is a three-year interval between births. Infants remain with their mother for a long period, allowing them to learn the complex foraging techniques needed for survival.

As if its striking appearance wasn't enough, it is the aye-aye's feeding habits that really set it apart. It is omnivorous, though insect grubs and ramy nuts Canarium sp. make up 90 per cent of its diet at times. Combining elements of both woodpeckers and squirrels (neither of which are found in Madagascar), it hunts for beetle grubs in rotting wood and uses its bony middle finger (the third digit) to extricate them. In contrast the fourth digit is more robust, so is used for tasks needing more strength such as accessing large fruit, scooping contents and exploring deep recesses.



Bristol Zoo's Lynsey Bugg with Noah the aye-aye.

Aye-ayes in captivity

Keeping aye-ayes in captivity demands specialist knowledge and husbandry techniques – in Europe the species is found at only six zoos. Durrell Wildlife Park and Bristol Zoo have two of the best exhibits.

Durrell's Madelon Rusman says, "The aye-ayes' distinctive musky smell and warm enclosures create a special atmosphere, where the quiet is interrupted only by the animals' snorts and sniffs. Their diet is a careful balance of pellets, eggs, insects, fruit and vegetables, but coconut is their favourite." Rusman emphasises the importance of a rich environment offering plenty to do. "Aye-ayes can chew through anything if they are bored – even concrete. We conceal insect grubs in bamboo sticks to simulate more natural behaviour."

Lynsey Bugg from Bristol Zoo describes its aye-aye care regime: "As a precaution against gnawing we protect their enclosure's ceiling with wire mesh, and the doors are metal. Recreating natural conditions is crucial, so our nocturnal exhibit not only replicates the correct balance between day and night, but also mirrors seasonality." Bristol Zoo must be doing something right: towards the end of May one of its females gave birth, boosting the number of animals in Europe to 17, and those in captivity worldwide to 60.

Indeed most of the aye-aye's anatomical peculiarities derive from its foraging and feeding adaptations. The roots of its huge, rodent-like teeth extend far back into the jaw, resulting in the unusually wide spacing between the eyes. The middle finger on each hand is not only excessively thin, but also incredibly flexible and can rotate 360 degrees. Unlike other digits, it articulates through a ball-and-socket joint. The aye-aye also has an unusually large brain relative to the size of its body, a consequence of the complex hand, eye and auditory co-ordination that it requires.

ABOVE: the forest near the village of Andranotsimaty (left) is one of the best places to search for aye-ayes, but is unprotected and threatened by extensive gold-mining (right)

BELOW: the aye-aye (this one is female) is the world's largest nocturnal primate

Distribution dilemma

A quarter of a century after the Durrell 'rescue mission', are we any closer to knowing how many aye-ayes still survive in the wild? It's a tough question. The continuing destruction of Madagascar's forests is well documented, and this clearly correlates to there being fewer aye-ayes. However, as more research has taken place an unexpected picture has emerged. Not only have aye-ayes now been recorded at numerous sites that stretch the entire length of the eastern rainforest belt, but they have also been found in drier forests in the far north, and in a number of deciduous forest locations on the western side of the island. This makes the aye-aye the most widely distributed primate species in Madagascar, other than Homo sapiens. In light of this broad distribution, the IUCN downgraded the species' status to Near Threatened in 2008.

When the guide pointed the aye-aye out, my pounding heart made it hard to focus

However, over the past 25 years Patricia Wright and Ed Louis have been at the forefront of lemur research across the island, and their independent studies suggest we may need to think again. On Nosy Mangabe the home ranges for males were up to 215ha (females' are smaller), but in forests on the mainland they can be two or three times larger. And while aye-ayes can live in secondary forest, there is far more evidence of their presence in undisturbed

A female aye-aye foraging in the middle canopy and understorey of dry deciduous forest. Aye-ayes have no fixed breeding season

forests, perhaps because these areas contain more old and dead wood with insect larvae. There is only 6–7 per cent of original forest cover left in Madagascar, so these factors in conjunction with the aye-aye's taxonomy lead the two scientists to conclude that the species should instead be regarded as Critically Endangered.

I have been visiting Madagascar for more than 20 years, but have seen aye-ayes just seven times in the wild. My most recent encounter, in the dry forests near Daraina, was the most prolonged, though it only came about after a two-hour wait beneath a nest, followed by a long run to catch up with Amidou, a local guide and tracker. When he pointed the aye-aye out to me in the canopy, my pounding heart made it hard to focus. But eventually I saw the animal moving through the thinner branches then climb down a tree headfirst, its remarkable hands pulled into shapes resembling gnarled, contorted tarantulas. Stopping periodically, the aye-aye tapped the trunk with its middle finger, then listened for a grub concealed beneath. By the time it looked around for the next branch or trunk to jump to, the aye-aye was just 2m away, surely the closest you can get to a gremlin in this world.

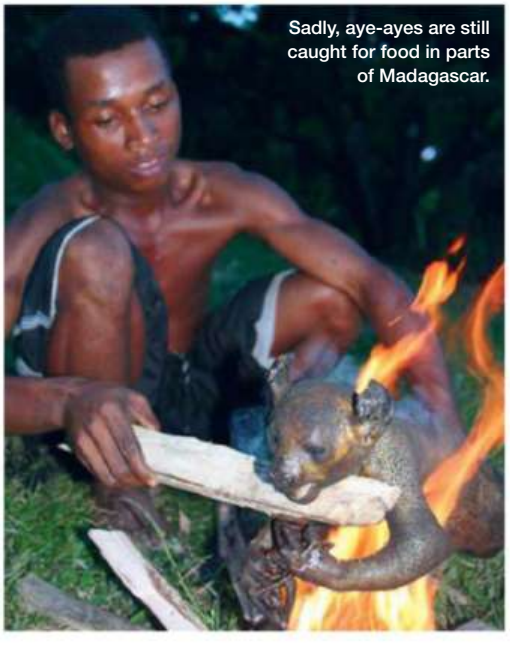
NICK GARBUTT is a photographer and author. Visit *http://nickgarbutt.com* to find out more.

Superstition, hunting and persecution

The aye-aye's appearance and nocturnal habits have contributed to it becoming entwined in Malagasy folklore. There are many superstitions with considerable regional variation, but the gist across much of the island is that the animal is associated with bad luck or evil, and considered taboo. This means aye-ayes suffer direct persecution. Beliefs seem to be most extreme in the far north: for example, their dead bodies or tails are hung on poles at crossroads outside villages in the Ambanja region to prevent deaths, because it is believed that passing travellers will carry any curse or ill-fortune away with them. In contrast, the aye-aye is held in high regard in some parts of the south-east: here the animal is believed to embody ancestral spirits, and accorded the same rites as a chieftain after death.

Chris Golden, a research associate at the Harvard School of Public Health and research director with the Wildlife Conservation Society, runs a public-health research programme in north-east Madagascar and has spent over 15 years in and around remote villages.

"The aye-aye is the source of fascinating and divergent cultural associations," he says. "In some areas the animal is considered a bad omen and is killed to avoid bad luck or even death befalling children in villages. In others, the aye-aye is just a strange-looking lemur. In the Makira region, where I work, local people hunt the species for food. This involves cutting a circular patch of forest around a large fruit tree. The tree is then connected back to the forest by bridging poles on which snares are set. Aye-ayes and other lemurs jump across into the fruit tree. When they are full, they climb back using the bridges and are caught."



Sadly, aye-ayes are still caught for food in parts of Madagascar.

BBC Knowledge

Highlights

TV Channel

Top Gear's Ambitious But Rubbish

Premieres 5th September. Weekends at 9.50pm (JKT/BKK), 10.50pm (SIN/HK/MAL/TWN)

Top Gear's Ambitious But Rubbish re-lives many of the greatest and boldest endeavours in all their splendour. Join Richard Hammond as he introduces some of the famous creations from the past Top Gear series, including the Train-Cars, James' Caravan Airship, the Hammerhead Eagle-i Thrust and the Hovervan.

Hidden Kingdoms

Starts 17th September,
Thursdays at 8.55pm (JKT/BKK),
9.55pm (SIN/HK/MAL/TWN)

It's time for the little guys to take centre stage. Prepare to be shrunk down and immersed into magical worlds packed full of tiny heroes living action packed lives.

Life Below Zero Sr 2

Tuesdays at 9.50pm (JKT/BKK),
10.50pm (SIN/HK/MAL/TWN)

Preparation for the brutal Alaskan winter dominate life for the hardy characters of *Life Below Zero*.

Extreme Fishing with Robson Green

Wednesdays at 8.55pm (JKT/BKK),
9.55pm (SIN/HK/MAL/TWN)

Robson Green is taking extreme fishing to a different level, testing himself to the limit to outwit the biggest, the weirdest, the most aggressive, and the hardest to catch fish ever.

www.bbcasia.com BBC Knowledge Asia @BBCKnow_Asia

BBC Knowledge is available in Hong Kong, Indonesia, Malaysia, Mongolia, Singapore, South Korea, Taiwan, Thailand and Vietnam.
Please call your cable operator for more details or check out our website.

Scan this QR Code for the audio reader

PHOTO: SCIENCE PHOTO LIBRARY

WHERE ARE ALL THE

HABITABLE PLANETS?

The number of known planets is increasing all the time, but how soon can we expect to find life? Stuart Clark takes a closer look

Back in March, a team at the Niels Bohr Institute in Copenhagen used a 250-year-old equation called the Titius-Bode Law to predict the number of habitable planets. The researchers stated that billions of stars will have one to three planets in their 'Goldilocks Zone', also known as a habitable zone (see p56). While the law gives a simple means of predicting the orbits of planets around a star, it isn't particularly accurate – even when applied to the Solar System.

Still, a lot of researchers believe that there are a significant number of Earth-like planets out there somewhere, many even within the Milky Way.

Astronomers call these Earth-like planets 'Earth analogues'. At the time of writing, there are 1,211 known planetary systems, with 482 of those sporting more than one planet. The current total of known planets sits at 1,918. These numbers increase all the time as new discoveries are made by various space programmes. Some of the planets so far observed are Earth-sized, some are in similar orbits to Earth, and some are around Sun-like stars. But not a single one ticks all three of these criteria. Astonishingly, of these hundreds of planets, not one is Earth's twin. Does this mean that Earth analogues are rare? With several missions planned for the coming years by NASA and others, will we soon find our planet's sibling?

Prof Geoffrey Marcy, from the University of California at Berkeley, was one of the first people to find planets around other stars. Back in 1995, he began reporting a string of planetary discoveries that continues to this day. In 2013, he and two colleagues began to wonder how close the nearest Earth-twin might be.

Kepler-186f confirmed that there are Earth-size, habitable planets outside the Solar System

"The nearest Sun-like star with an Earth-size planet in its habitable zone is probably only 12 light-years away and can be seen with the naked eye"

Erik Petigura, University of California at Berkeley

To find out, they trawled through data collected by the Kepler telescope. Launched in 2009, it continually monitored 145,000 stars until 2013, when a malfunction in its guidance system ended the mission. Marcy and colleagues analysed data from 42,000 stars in the survey. The signature they were looking for was a dimming in the star's light. When a planet passes in front of its parent star, its silhouette dims the star slightly and the telescope can measure this.

Using this technique, they discovered 603 planets. Ten were more or less Earth-sized and received something comparable to the light that Earth receives. None of the planets were Earth's twin, but in analysing the results statistically, they reached the conclusion that one in five Sun-like stars could harbour an Earth analogue.

"When you look up at the thousands of stars in the night sky, the nearest Sun-like star with an Earth-size planet in its habitable zone is probably only 12 light-years away and can be seen with the naked eye. That is amazing," said UC Berkeley graduate student Erik Petigura, who led the analysis of the Kepler data.

To help quantify the Earth-like properties of a planet, astronomers have concocted the Earth Similarity Index (ESI). It looks at a planet's radius, density, escape velocity and surface temperature and compares it to Earth. Planets are given a grade on a scale between 0 and 1, with a score of 1 indicating a planet exactly like Earth.

Using this scale, the planet most similar to Earth is KOI-1686.01. KOI stands for Kepler Object of Interest and is a temporary designation given to planet

EXPLAINED: THE 'GOLDILOCKS ZONE'

This is the region around a star where the atmospheric conditions for orbiting planets are 'just right' to support liquid water. The exact location of the zone varies depending on how hot the star is…

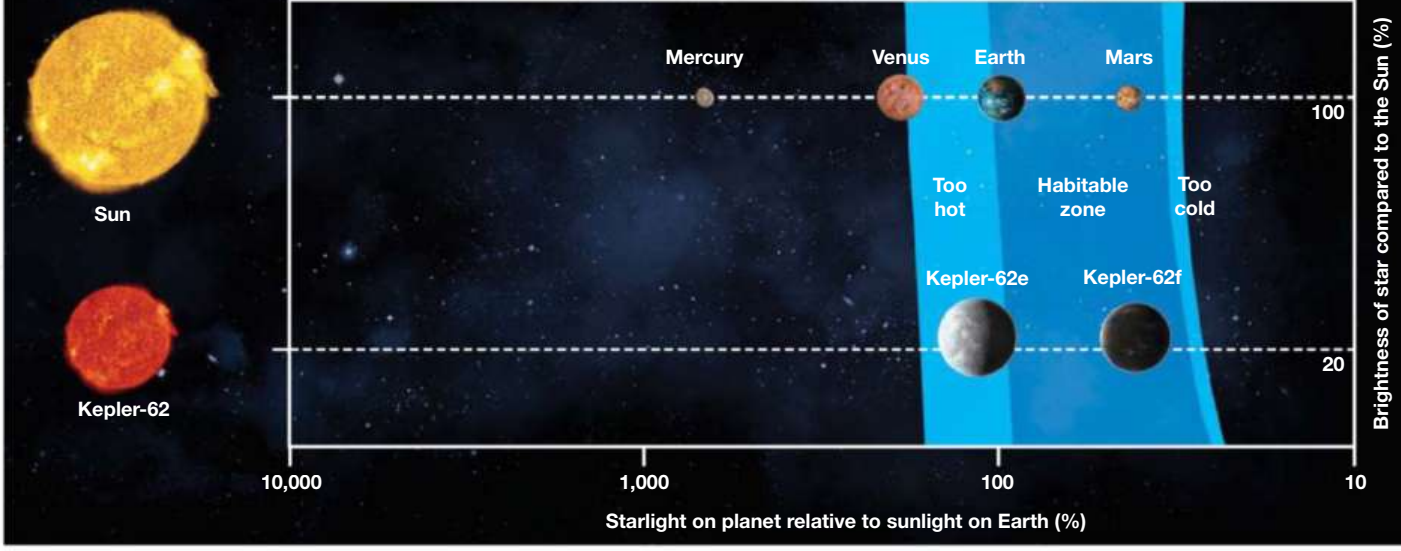


PHOTO: NASA/KEPLER, JOHN D & CATHERINE T/ MACARTHUR FOUNDATION

candidates before they are confirmed. In this case, KOI-1686.01 is 1.33 times the radius of Earth. Although it orbits a dim red dwarf star, it is so close that it receives enough heat to allow surface water to be liquid. When everything was evaluated, its ESI came out to be 0.89. In our own Solar System, Mars has an ESI of just 0.69. Unfortunately, follow-up observations have failed to spot the planet for a second time.

Water world

To be counted as real, a planet must be seen first as a dimming of the star, and then

Prof Sara Seager is confident that if there are Earth-like planets out there, her team will find them

EARTH 2.0?

Kepler was specifically designed to scan our region of the Milky Way for planets in the habitable zones of their central stars. Here are a few candidates that could support life…

Artists' impressions of some of the exciting exoplanets orbiting stars other than our own

KEPLER-438b

This planet was confirmed on 6 January 2015. Kepler-438b is thought to be a rocky planet and is just 1.12 times the radius of Earth. It is situated 470 light-years away, where it orbits a red dwarf star once every 35.2 days. Even though its star is cooler than the Sun, its close proximity means that it receives 1.38 times the solar energy that Earth does.

KEPLER-442b

This planet is 1,120 light-years from Earth and 1.34 times our planet's radius. Although its parent star is a little cooler than the Sun, the planet's orbit means that it receives 0.66 of Earth's input energy. Kepler-442b orbits its parent star once every 112 days. Its discovery was announced at the same time as Kepler-438b.

confirmed using a ground-based telescope to look for the wobble on the star that the planet's gravity causes.

So, no second Earths yet. But that doesn't mean that some of the planets so far detected cannot be habitable. They'd just be more like Earth's cousins than Earth's twins. "For me, two planets stand out head and shoulders above all the others," says Marcy. "The first is Kepler-186f. This is almost exactly Earth-sized but only receives about one-third of the warmth from its star that Earth receives from the Sun. The second is Kepler-62f. This is 1.4 times bigger than Earth and receives around 40 per cent of Earth's energy."

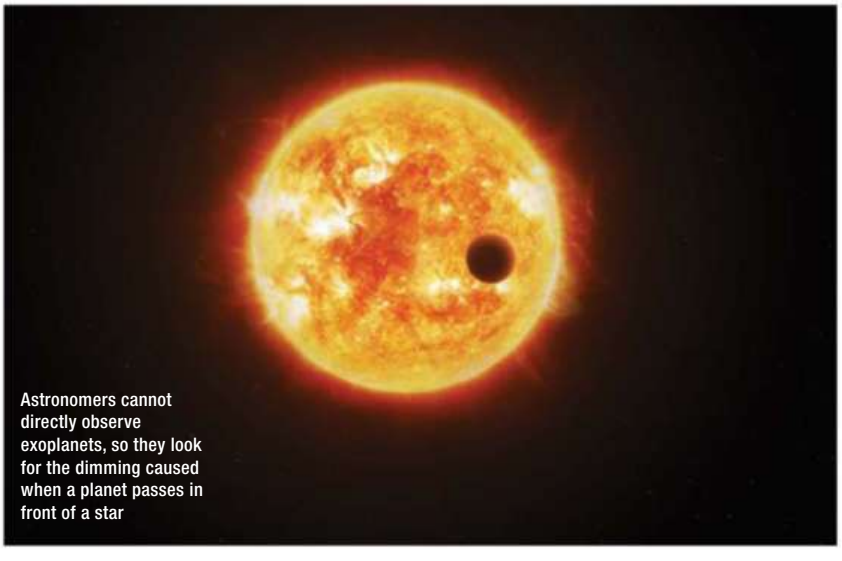
Habitability rests, first and foremost, on the planet being warm enough for liquid water to exist so that biochemical interactions can take place.

A planet receiving much less energy than Earth receives from the Sun may seem as if it is too cold, but a planet's atmosphere can play a big role.

We hear a lot about the greenhouse effect, which is an atmosphere's ability to trap heat. Because of its association with industrial waste gases, we tend to think of it in a negative way, yet we rely on the greenhouse effect's warming action to keep the Earth habitable.

"If there is a rocky planet transiting a small star in the habitable zone of that star, we will find it"

Prof Sara Seager, Massachusetts Institute of Technology



Astronomers cannot directly observe exoplanets, so they look for the dimming caused when a planet passes in front of a star

"Earth would be freezing without a greenhouse effect," confirms Marcy. So his two choices would have to rely on a greenhouse effect to compensate for the lack of energy they receive directly. In the case of Kepler-62f, its larger size will generate more gravity, thus ensuring a thicker atmosphere than Earth, which boosts its greenhouse effect.

A new generation of searches for habitable planets is on the horizon, with two new space missions that will follow on from the techniques of Kepler. They are being developed on either side of the Atlantic, and both rely on the transit method of detection. More sensitive telescope detectors will allow smaller planets to be seen.

The European Space Agency (ESA) is building CHEOPS (CHaracterising ExOPlanet Satellite) for launch in 2017. It will study nearby star systems that are

PHOTO: NASA/AMES/CALTECH X4, DAVID A AGUILAR/CFA, ESA/C CARREAU, ESA/ATG MEDIALAB

KEPLER-186f

Kepler-186f was announced in April 2014 and is perhaps the closest match to Earth so far. Although some began dubbing it Earth 2.0, it's not identical. While it is 1.1 times the radius of Earth, its star is dimmer than the Sun and Kepler 186f receives just a third of Earth's input energy.It was the first Earth-size planet to be found orbiting in the habitable zone of a star.

KEPLER-62F

This is the outermost of a five-planet system orbiting the star Kepler-62. At 1.4 times the radius of our planet, it is termed a super-Earth. It receives just 0.41 times the amount of solar energy of the Earth, but its extra bulk will provide more gravity to attract a thicker atmosphere that could give rise to a lifesaving green-house effect.

KEPLER-62e

This planet is a sister world to Kepler-62f and is another super-Earth. It is located at the inner edge of the star's habitable zone so it receives more energy than the Earth. The discovery of the two potentially habitable worlds around Kepler-62 prompted a congressional hearing in the US dubbed 'Exoplanet Discoveries: Have We Found Other Earths?'.

already known to have planets, with a goal of measuring those planets' radii and to look for other worlds that have so far escaped detection.

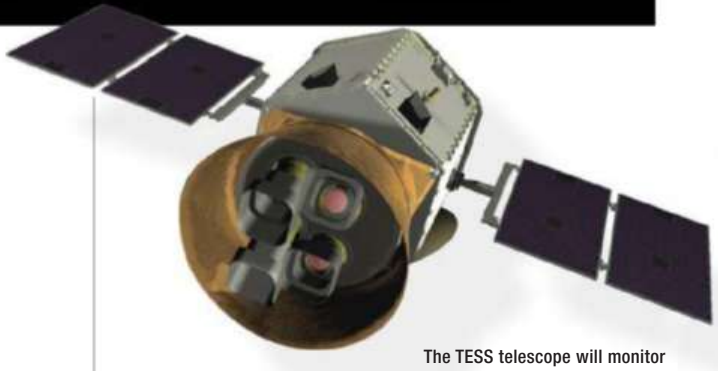
A closer look

Simultaneously, NASA is planning the Transiting Exoplanet Survey Satellite (TESS). This too will launch in 2017. It will use four onboard wide-angle telescopes to survey half a million stars across the sky. The mission team estimates that TESS could find between 1,000-10,000 planets.

The driving scientist behind TESS is Prof Sara Seager of the Massachusetts Institute of Technology. She is in no doubt about the goals and abilities that TESS will have. "If there is a rocky planet transiting a small star in the habitable zone of that star, we will find it," she says.

She hit the headlines in 2013 by describing an equation that could be used to estimate how many planets with detectable signs of life may be discovered over the coming years.

The various terms in the expression included the number of stars to be observed, the fraction of those stars that we expect to have planets in their habitable zone, and the fraction that have sufficient life to produce an observable signature. Seager estimated that some terms, like the number of stars observed, can be assigned real values. But other terms, such as the fraction that have detectable life signs, remain speculative. As a result, her equation cannot give a definitive answer but she still believes that it was still a worthwhile exercise. "I wanted the world to know that we are doing the real search for alien life," she says.



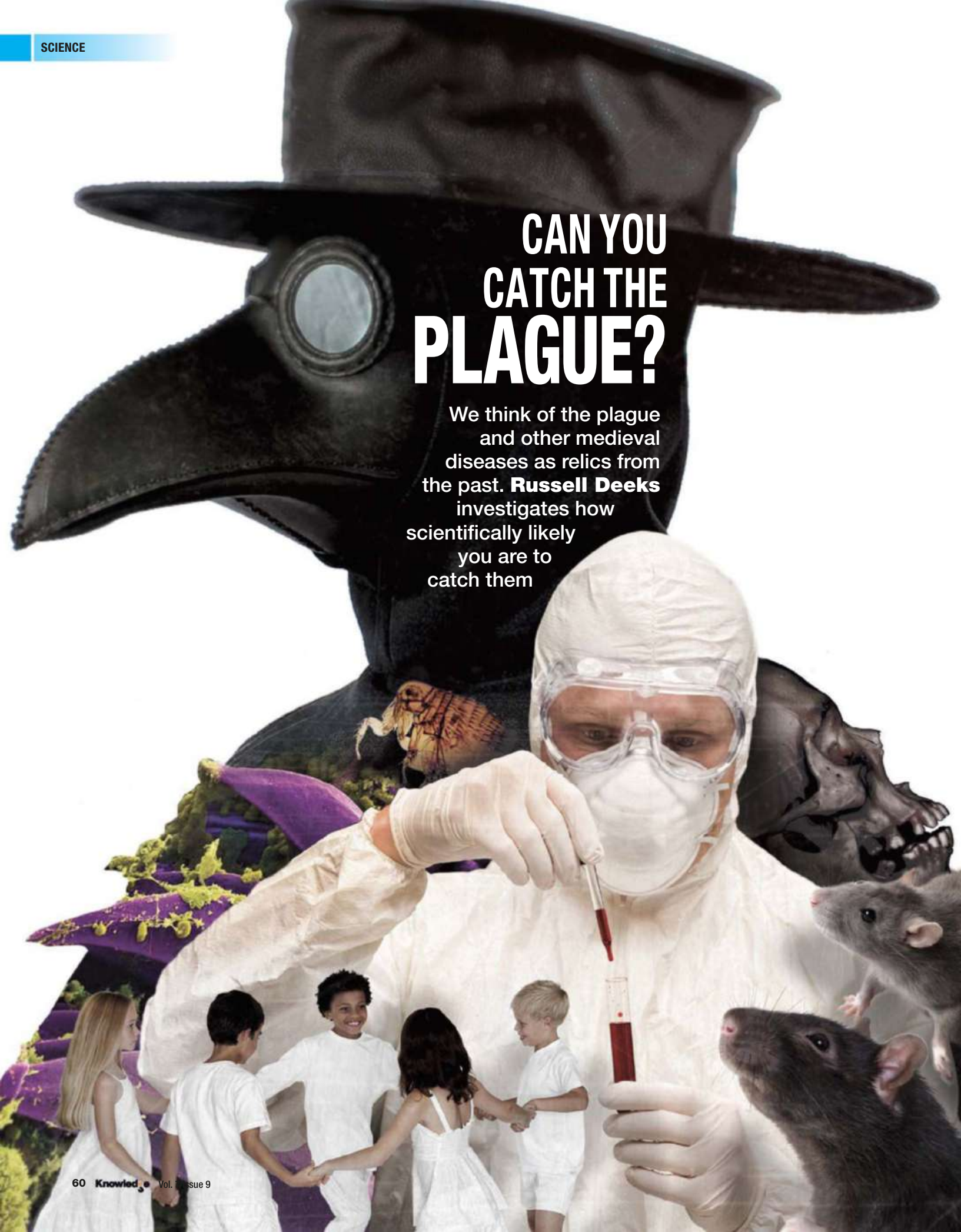
The TESS telescope will monitor half a million stars for planets in their habitable zones

The first step towards that goal is finding as many habitable planets as possible. Astronomers already have some in the bag, but CHEOPS and TESS should advance the search significantly. E.T. – we're coming! ■

STUART CLARK is an astronomy writer and author of the forthcoming *The Unknown Universe: What You Need To Know About Time And Space*

CAN YOU CATCH THE PLAGUE?

We think of the plague and other medieval diseases as relics from the past. **Russell Deeks** investigates how scientifically likely you are to catch them



Ring-a-ring o' rosies, a pocket full o' posies. A-tishoo! A-tishoo! We all fall down. For most of us, this deceptively macabre nursery rhyme is the sole legacy of the bubonic plague, a killer disease that once wiped out a quarter of Europe's population. Bubonic plague has, we tend to assume, been safely relegated to the dustbin of medical history.

Except that's not true. Europe may have been largely free of the disease since the early 18th Century, but unlike smallpox, it's never been truly eradicated. Outbreaks of bubonic plague still occur fairly regularly in the developing world, while even in the USA there are seven cases a year, on average. So should we be worried?

Horrible history

Bubonic plague is caused by the bacterium Yersinia pestis. This rod-shaped, anaerobic microbe lives in the guts of fleas, which in turn live on small rodents including rats, gerbils and prairie dogs. Should an infected flea then bite a human being, the bacterium attacks the lymph glands in the armpits and groin, causing the characteristic swellings – buboes – that give the disease its name. Sufferers also experience flu-like symptoms: severe fever, chills, muscle cramps, aching limbs, coughing and difficulty breathing. Gangrene and haematemesis (vomiting blood) can also occur.

If untreated, 60 per cent of victims will die within a few days. If antibiotics are given within 24 hours of symptoms appearing, however, the mortality rate drops to less than 15 per cent.

If the infection spreads to the bloodstream, it is known as septicaemic plague; if it spreads to the lungs, it becomes pneumonic plague. The latter is particularly troublesome because this form of the disease can be spread directly between humans.

There have been three major plague pandemics. The first, the Plague of Justinian, occurred in the 6th Century in the Byzantine Empire. This killed an estimated 25 million people, with another 25 million dying in smaller outbreaks over the next 200 years. The second, the Black Death, spread right across Europe in the mid-1300s, killing 200 million. The third pandemic, in the late 19th and early 20th Centuries, was largely confined to Asia and the Far East, and killed 12 million people in China and India alone. The Great Plague of London that occurred from 1665 to 1666 was a mere sideshow in comparison. It saw 100,000 people – 25 per cent of the city's population – die of the disease.

The third pandemic was not officially declared over until the 1950s. Yet outbreaks still occur, with the majority occurring in sub-Saharan Africa. In Zambia, for instance, an outbreak in 1997 caused 26 deaths.

Very recently, bubonic plague hit China and Madagascar. In July 2014, the 30,000 inhabitants of Yumen, in the Chinese province of Gansu, found their town closed off from the world after a 38-year-old man died from the disease. Then, between August 2014 and February 2015, 71 people died from plague in Madagascar. This island sees fairly regular occurrences of the disease, partly due to slum conditions.

"We found a total of 545 fleas on only 133 rats. It was quite a surprise to find so many"

Matthew Frye from Cornell University's New York State Integrated Pest Management Program

Bubonic plague can inhibit circulation to the tissues, causing the affected area to rot and die

The third plague pandemic took place in Asia. Carts like this were used to remove dead bodies

PHOTO: ISTOCK X6, SCIENCE PHOTO LIBRARY, US LIBRARY OF CONGRESS

PHOTO: C FIRTH, MCMASTER UNIVERSITY X2, GETTY, SCIENCE PHOTO LIBRARY X3, WELLCOME TRUST COLLECTION

Plague in the USA

Recently, plague watchers' eyes have turned to New York City, thanks to two separate studies that found risk factors for the disease. A study led by Matthew Frye of Cornell University's New York State Integrated Pest Management Program found Oriental rat fleas – the type that carry the Y. pestis bacterium – on NYC rats, while one carried out by Cornell's medical school found the Y. pestis bacterium itself on the city's subway. However, no infected fleas or rats were found, so no need for New Yorkers to panic just yet…

"We sort of expected to find Oriental fleas because we knew that historically they were in the city, but what surprised us was the number. We found a total of 545 fleas on only 133 rats," says Frye. "It was quite a surprise to find so many. But none of the fleas were carrying the plague

Matthew Frye scoured New York in his hunt for Oriental fleas

Teeth from plague victims contain DNA from *Yersinia pestis*

THE PLAGUE IN NUMBERS

REPORTED PLAGUE CASES BY COUNTRY 2000-2009

New research suggests that gerbils, rather than rats, could have caused the spread of the Black Death

Vaccines are available, but are not very effective in combatting plague. They are used by lab and field personnel working with the disease

1900

The first case of plague in the US occurred at the turn of the 20th Century. The disease arrived from the San Francisco docks

bacterium, and none of the rats had plague. The other study found a number of strange bacteria in the subway system that they didn't expect to, but this is still a developing area of study. We don't yet know how that translates to human disease, whether these things that are found on structures and surfaces are being acquired by humans or cohabiting organisms. But we do know it's not easy for any animal, whether a rat or a human, to pick up plague bacteria that are in the environment."

But what if the bacterium were to evolve? A third study, carried out in 2014 by a team led by Dave Wagner, from the Center for Microbial Genetics and Genomics at Northern Arizona University, looked at how the bacterium itself has evolved over time, concluding that different pandemics were caused by different strains of Y. pestis.

"We used teeth from suspected victims of the first pandemic," says Wagner. "Teeth are a good sample for obtaining DNA of blood-borne pathogens as you have a lot of blood vessels feeding your dental pulp. Teeth act as a sort of time capsule for ancient DNA. Most of the DNA in the sample will obviously be human, but if the person died of plague there will be some Y. pestis DNA in the sample as well. So we 'pulled' the Y. pestis DNA out of the total DNA," he explains.

"We found that the three pandemics were definitely caused by different strains," Wagner continues. "But we also found that the strains associated with the three human pandemics are pretty much identical in their DNA to the Y. pestis strains found around the world today in different rodent populations. That suggests that pretty much all Y. pestis strains are capable of causing pandemics given the right conditions. The reason we don't have pandemics any more isn't because Y. pestis has changed, it's because human behaviour has changed."

Don't have nightmares

And that, in a nutshell, is why you needn't worry too much. Even if an outbreak of plague were to occur, as Wagner points out, "We now have antibiotics, and plague is easily treated with almost any antibiotic." Or as a World Health Organization fact sheet puts it: "Early diagnosis and treatment is essential for survival and reduction of complications [but] antibiotics and supportive therapy are effective against plague if patients are diagnosed in time."

More importantly, now that the mechanism of plague contagion through fleas and rodents is understood, keeping the disease under control is simply a matter of good hygiene and sanitation.

In other words, if you don't want to die like a medieval peasant… try not to live like one. ■

DARK AGE DISEASES

Bubonic plague isn't the only medieval killer that's still lurking in the shadows…

Charles II touching King's Evil sufferers

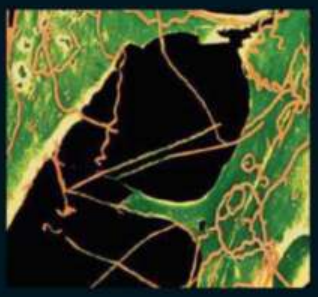
THE KING'S EVIL

So-named because it was believed being touched by the King would cure you, the King's Evil caused large, black swellings all over the sufferer's neck. Today we know this to be scrofula, a swelling of the lymph nodes due to infection by tuberculosis or other mycobacteria. With surgery and antibiotics, complete remission occurs in 95-100 per cent of patients – though it remains a danger to those suffering from AIDS.

Convulsions caused by ergot poisoning

ST ANTHONY'S FIRE

An epidemic in Paris in 945 AD saw huge numbers of victims covered in raw, red sores all over their bodies and afflicted by hallucinations, convulsions and gangrene. We now know that this was caused by poisoning due to long-term exposure to ergot – a fungus that affects rye, barley and other cereals. This fungus can now be detected and eradicated in cereal crops. In the modern world, the disease is now vanishingly rare.



Treponema pallidum causes syphilis

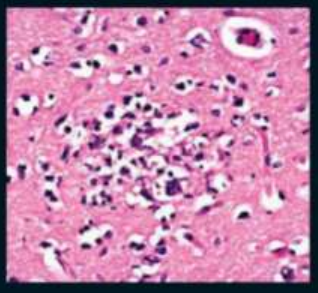
FRENCH POX

Otherwise known as syphilis, this is a sexually transmitted infection that causes lesions first on the sexual organs, then all over the body, along with fever, sore throat, headaches, rashes, liver inflammation and kidney disease. Basically, you don't want it. While infection isn't uncommon – with around 50,000 new cases in the US each year – it can now be treated with antibiotics. These days, fatalities are rare, though lasting organ damage can occur.

Cholera bacteria infect the gut

CHOLERA

This is caused by the ingestion of faecal bacteria, largely from contaminated drinking water. Symptoms include vomiting, muscle cramps and diarrhoea, leading to severe dehydration. If untreated, the mortality rate is as high as 50 per cent. During the 19th Century, six successive pandemics killed millions. Prevention, through access to clean drinking water, is the best cure, but cholera still kills upwards of 100,000 people worldwide a year.



Typhus is caused by *Rickettsia* bacteria

TYPHUS

Typhus – not to be confused with typhoid fever – is spread by lice and fleas carrying *Rickettsia* bacteria. It causes high temperature and pain throughout the body. If untreated, the mortality rate can reach 60 per cent. The first known epidemic occurred during 1489's Siege of Granada, when it killed 17,000 Spanish troops. The first vaccines were developed in the 20th Century, but it's still a problem in the developing world.

WASTE NOT, WAN

PHOTO: GENECO, DUNCAN KINNEY/GREEN ENERGY FUTURES

8

TRANSPORT FUEL

Methane is a simple product that can be created from human faeces. The main ingredient in the natural gas that is tapped from the ground before running throughout the national grid, methane heats our homes and cooks our food. But it can also be produced in anaerobic digesters, in which microbes degrade food scraps and other organic material in the absence of oxygen. Methane can even be made straight from sewage. To prove that 'not everything we flush goes to waste', the FirstGroup transport company is running the first bus in the UK powered by poo. The Bio-Bus – launched in March 2015 – uses biomethane provided from the GENeco waste recycling and renewable energy facility in Avonmouth. The 41-seater bus runs along the aptly named number 2 route that links Cribbs Causeway in north Bristol to the south of the city.

The innovative vehicle can run for up to 300 kilometres on one tank (the equivalent of five people's annual flushes). If successful, and if riders approve of travelling on human emissions, the company hopes to roll out even more 'poo buses'.

T NOT

Each day, we could be flushing millions of dollars down our collective loos. Zoe Cormier examines eight ways the world can harness human waste

The gas is stored in the top of the Bio-Bus. Its CO_2 emissions are around 20-30 per cent lower than those from diesel

7

ANIMAL FEED

An innovative feed for farm animals is being developed by researchers at the Sanitation Ventures group at the London School of Hygiene & Tropical Medicine. Their work is largely funded by the Bill & Melinda Gates Foundation's Reinvent the Toilet Challenge, which is aimed at helping the 2.5 billion people worldwide who lack sanitation.

According to Dr Jeroen Ensink, Senior Lecturer in Public Health Engineering at the London School of Hygiene & Tropical Medicine, they wanted to find a way to safely remove the human waste from latrines, but also generate a bit of income for these communities. Their solution was to use black soldier fly larvae to degrade the human waste. The plump larvae were then turned into a protein-rich product to be sold as fish food or chicken feed. Tests to see if meat and eggs that derive from human faeces-fed larvae are safe for consumption are taking place right now, says Ensink.

These dried black soldier fly larvae can be used for animal feed

6 RADIATION SHIELDS

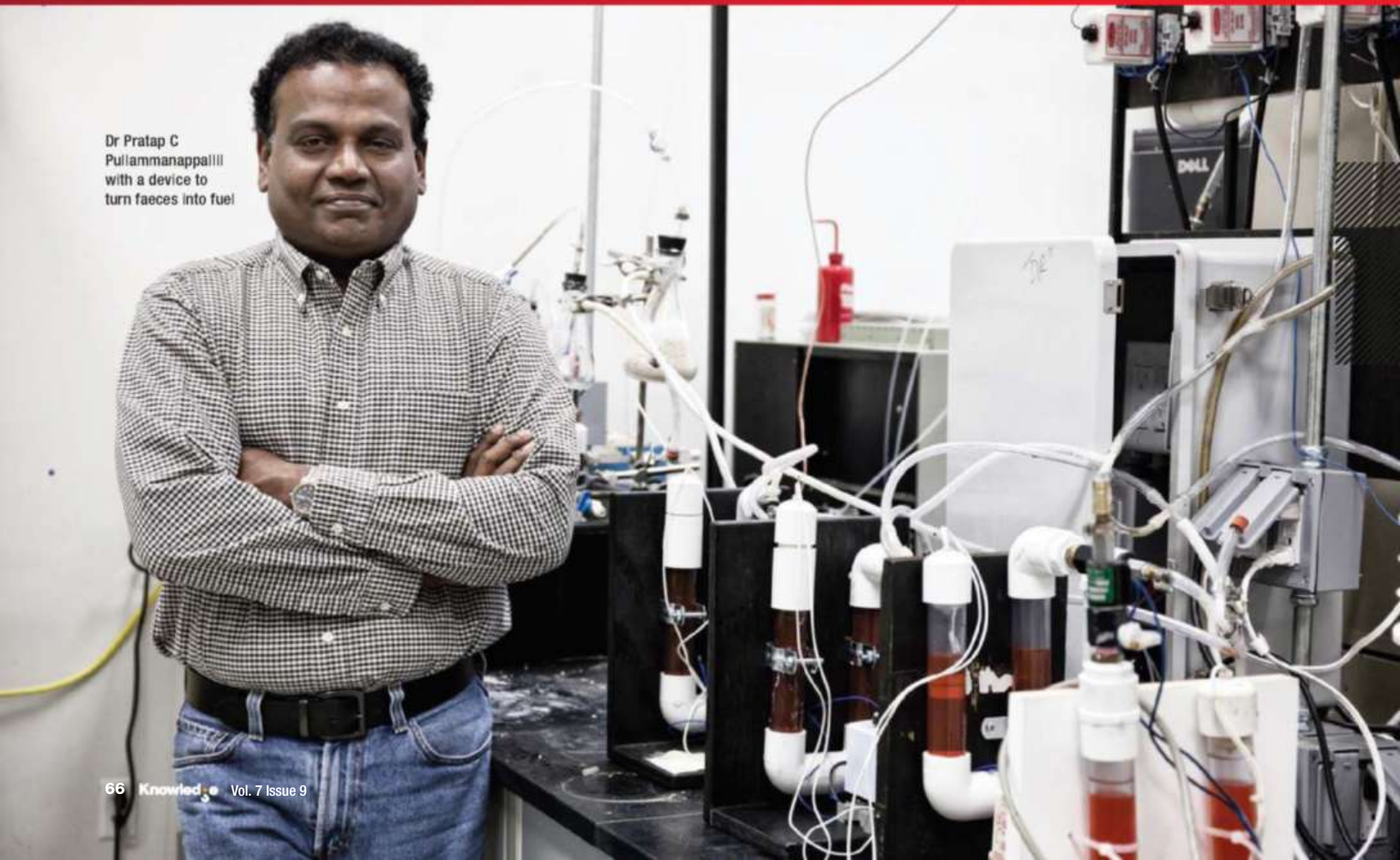
While NASA shelved its plans for a base on Mars, and later its intentions for a lunar station, others have not given up on the interplanetary dream of putting humans on other planets. Mars One, for example, aims to send humans to a permanent base on Mars by 2026. Meanwhile, Inspiration Mars – a private venture founded by American Dennis Tito – plans to send adventurers on flyby missions to the Red Planet by 2018.

One of the greatest hazards of interplanetary travel will be cosmic radiation, which is estimated to increase the risk of cancer by 3 per cent. Inspiration Mars's solution? Line the walls of the space shuttle with water, food, and excrement. Could the power of poo really help us conquer the cosmos? Perhaps Oscar Wilde put it best: "We are all in the gutter, but some of us are looking at the stars."

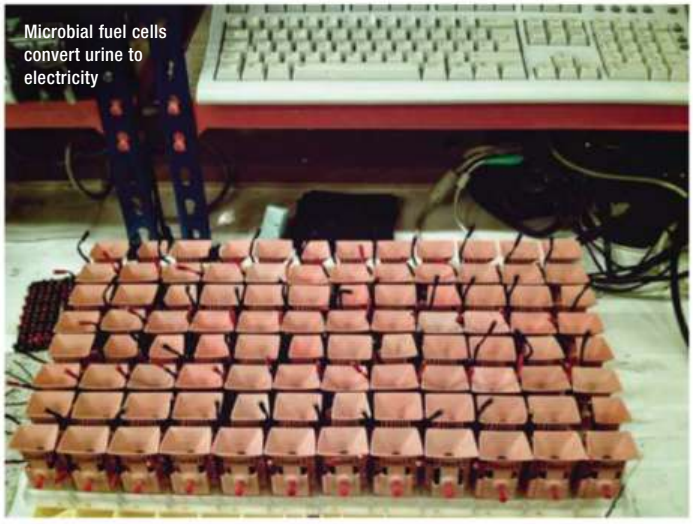
Interplanetary travellers could visit Mars via a poo-lined space shuttle

5 ROCKET FUEL

In space, what do you do with your poo? Early astronauts simply bunged their dung in a bag. This proved inadequate, and led to some unfortunate situations. Back in 1969 on NASA's Apollo 10, Commander Tom Stafford is quoted as saying: "Give me a napkin, quick. There's a turd floating through the air." Modern space loos are more sophisticated, yet they make the same mistake: not putting those turds to good use. Instead, scientists from the University of Florida suggest that lunar bases could convert faeces into fuel. They came up with a technique that would enable 290 litres of methane to be produced per astronaut per day – enough to power their rocket back to Earth. As a bonus, water from waste could be split into hydrogen and breathable oxygen. "We began working on this idea back in 2002, when NASA wanted us to help them plan for using waste for fertiliser and fuel in a base on Mars," says Dr Pratap C Pullammanappallil, who worked on the research.



Dr Pratap C Pullammanappallil with a device to turn faeces into fuel



Microbial fuel cells convert urine to electricity

3 POO TO PLATE

The simplest way to make good use of waste is to use faeces as fertiliser. Throughout history, human waste has been used on fields in nearly every culture on Earth. Today, the thought of using our own excrement to grow food may seem revolting, but the tradition continues in developed countries. For example, roughly 60 per cent of biosolids – the sterilised end-products of wastewater treatment facilities – are spread onto land in the US (usually fallow fields or tree plantations). In developing countries, however, untreated sewage is frequently taken from open pit latrines and used on farmland. While raw sewage is cheaper than traditional fertilisers, its usage can often lead to increased numbers of microbes and parasites. Thankfully, safer solutions are being devised. One innovative example is the Tiger Toilet, which is being developed at the London School of Hygiene & Tropical Medicine. The simple loos are filled with tiger worms that can convert poo to compost in about six months.

Tiger worms eat poo and create compost

4 PEE POWER

Poo isn't the only powerful excretion – there is a urinal at the University of the West of England that can generate electricity from pee. The unit, which is partly funded by Oxfam, could bring power to off-grid locations such as refugee camps. The urinals contain microbial fuel cells, which are filled with live microbes that feed on urea. The system accesses the biochemical energy the microbes use for growth and converts it to electricity.

"This first step shows we can power lights inside the cubicle," says Prof Ioannis Ieropoulos, from the Bristol BioEnergy Centre at the university. "The next challenge is generating enough electricity to go beyond the urinal." Their research – which began 13 years ago – did not start with pee. The team initially investigated potential fuels for autonomous robots and examined the electricity that could be produced with various waste materials, such as grass clippings and shrimp shells. "Urine actually proved to be one of the best feedstocks for electricity production," says Ieropoulos.

"This first step shows we can power lights inside the cubicle. The next challenge is generating enough electricity to go beyond the urinal"

Prof Ioannis Ieropoulos, Bristol BioEnergy Centre at the University of the West of England

PHOTO: MARS ONE, OXFAM, AMY STUART/UF IFAS COMMUNICATIONS

2 HYDROGEN FUEL

The hydrogen in hydrogen fuel cells is obtained via the electrolysis of water. A current is passed through water to obtain hydrogen and oxygen molecules. Using the same technique, oxygen and hydrogen can be cleaved from ammonia and urea – two of the main compounds in pee. In fact, the process is far more efficient with urine because less energy is required to obtain the substances.

Researchers at the University of Ohio are looking to harness this power in urine to generate electricity from large buildings, such as offices and sports stadiums. Meanwhile, a team at Caltech (another Bill & Melinda Gates Foundation winner) is working on solar-powered urinals with the capacity to generate hydrogen gas that can be stored as a back-up source of energy. One problem: researchers have waxed lyrical over the promise of the hydrogen economy for decades, with few results. Are these hydrogen visionaries just pissing in the wind? Time will tell.

Caltech graduate student Clement Cid with the team's solar-powered urinal

University of Ohio researchers with their 'S-pee-d Racer' car, which runs on hydrogen extracted from urea

1 MINE FOR GOLD

Talk about turning trash to treasure: scientists are looking at ways to extract precious metals – including gold, silver, platinum, copper and titanium – from sewage. What's more, the amount is far from insubstantial: the waste produced by a million Americans every year could contain as much as US$13m worth of metals. According to Dr Paul Westerhoff from Arizona State University, it's unclear exactly where these metals are coming from because municipal sewage derives from more than just domestic origins. Waste from dentists' offices is one likely trove because gold and silver is used in dental amalgams, while other potential sources are the cosmetics and personal care products that go down the drains.

But poo could also be serving up the goods: titanium dioxide, for example, is added to many doughnuts. Whatever the source, more research is needed to figure out where the metals are coming from and how to extract them. "If we really can mine US$13m per year from a community of a million people, we could not only reduce the cost of treating municipal waste, we could also reduce the need to mine these metals from traditional sources," says Westerhoff. "By reducing the need for mining, reducing the amount of metals that wind up on land and in forests as biosolids, and extracting something of value that reduces overall treatment costs, it's a potential big win."

This all points to a much bigger issue. Just as we now increasingly view paper, plastic and metal waste from households as a resource to be recycled rather than rubbish to be discarded onto landfills, we may need to think of our own excrement in the same way. We could call it urban mining, perhaps? Dr Jeroen Ensink of the London School of Hygiene & Tropical Medicine agrees. "We can only tackle the sanitation problem when we make it a commercial success. Only when you can turn waste into an asset will people start investing in its proper treatment."

But is it really possible to extract these precious metals from faeces? "I have already told one of my PhD students that she won't graduate until she gives me a gold ring made in this way," chuckles Westerhoff.

Microscopic particles of gold and lead (yellow flecks) in a biosolid sample. The metals may come from various sources, including dental amalgams, food and cosmetics (pictured below)

ZOE CORMIER is a science writer with a background in biology

RISING FROM THE ASHES

Seventy years ago, Hiroshima was decimated by the Little Boy atomic bomb. Mun Keat Looi charts the city's unexpected recovery in the weeks and months following the blast

Scan this QR Code for the audio reader

PHOTO: SCIENCE PHOTO LIBRARY, GETTY. ILLUSTRATION: ANDY POTTS

"Looking up, the orange colour of the Sun, along with the sound of the plane overhead. As I covered my head a huge bang came and the entire barracks was blown away, many people losing consciousness as a result. From behind a windowsill, the hell that was the reality in front of me was being taken in by my eyes, accompanied with the groans of its victims"

Hiroshima survivor

Hiroshima, Japan, Monday 6 August 1945. At 8.15am, the US bomber Enola Gay dropped 'Little Boy', the first nuclear weapon ever used in warfare. Measuring just 300cm in length and 70cm in diameter, the atomic bomb was the pinnacle of the Allies' US$2m Manhattan Project. It was a marvel of scientific engineering, and an awesome show of military might delivering unprecedented destruction. Just three days later, Fat Man exploded over the city of Nagasaki. These remain the only two instances of nuclear bomb use in a warfare situation.

Little Boy detonated just 43 seconds after its release, and the 4,400kg payload unleashed a punch equivalent to 15 kilotonnes of TNT. Little Boy missed its target, which was the T-shaped Aioi Bridge traversing the city's Ota and Motoyasu rivers, because the wind carried it around 250m away. There, it detonated 600m above ground, reportedly over a surgical clinic.

The explosive trigger set off the real mechanism. The bomb contained radioactive uranium-235, which was pushed into a spiral of decay. Each atom broke down to release neutrons, gamma rays and a huge amount of energy. These parts in turn destabilised neighbouring uranium atoms, in a nuclear fission chain reaction that used up 10 per cent of Little Boy's 64kg of uranium stock.

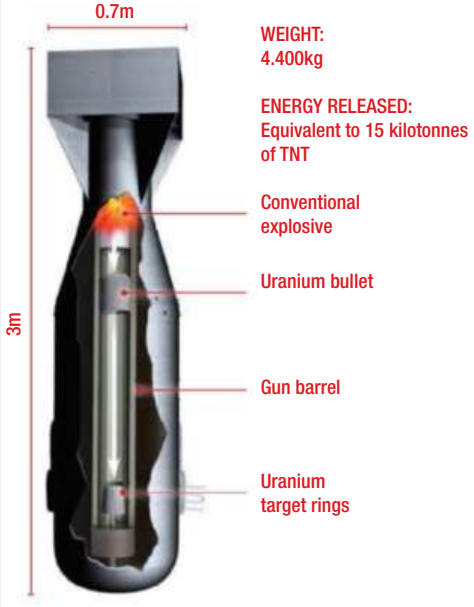
Within one second, a fireball 280m in diameter burst forth with a core temperature of over 1,000,000°C. Its heat rays raised surface temperatures to between 3,000°C and 4,000°C (iron melts at 1,500°C), scorching anything exposed to it. Birds burst into flames mid-flight. Paper as far as 2km away ignited. Entire houses were set alight, and structures collapsed in fires that would rage for another six or seven hours.

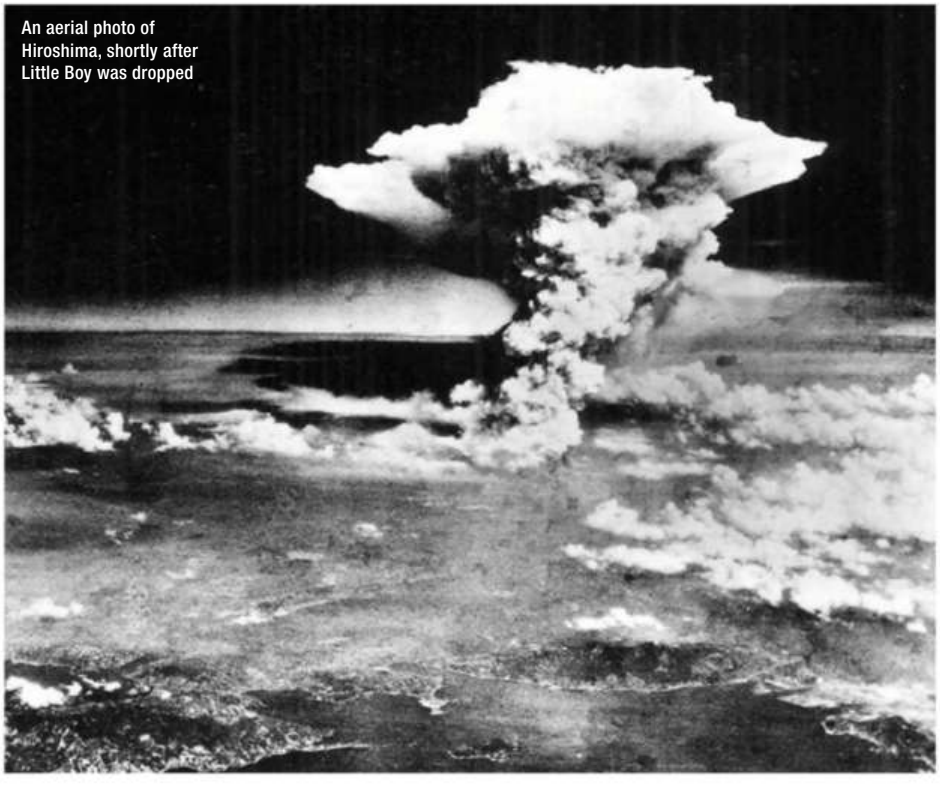
Heat blast

The extreme temperature rise suddenly expanded the air around it, generating a tremendous blast travelling faster than sound. Just 500m from the centre of the blast, the atmospheric pressure reached 19 tonnes per square metre. Anyone not already incinerated was blasted by the splintered glass of exploding buildings – survivors alive today still have fragments embedded in their bodies. Then, a reverse. The sudden drop from high to low air pressure in the space behind the blast caused a tremendous backdraught, popping the eyeballs and internal organs of anyone unfortunate enough to be caught in it. Nearly everyone within a kilometre of the detonation centre (the 'hypocentre') died.

In fact, it could have been worse. Had Little Boy delivered its payload into the ground and not exploded in mid-air, its toll to the population and environment could arguably have been higher. As it was, it was still devastating. As the fireball rose, the ascending air currents surged into the stratosphere, carrying the remaining 90 per cent of Little Boy's radioactive material – which hadn't undergone nuclear fission – with it. Those who came near the hypocentre for rescue and relief or to search for their families absorbed radiation and fell ill.

The Atomic Bomb 'Little Boy'




An aerial photo of Hiroshima, shortly after Little Boy was dropped

BLAST RADIUS OF HIROSHIMA

Effect of a 15 kilotonne atomic bomb

Fireball
The Little Boy bomb was detonated 600m above the city. A fireball measuring 280m in diameter exploded forth, raising surface temperatures up to 4,000°C

All buildings collapse
Even heavily built concrete buildings are severely damaged or demolished; fatalities approach 100 per cent.

High levels of radiation
Those closest to the bomb received the highest doses of radiation.

Residential buildings collapse
The atom bomb destroyed 76,000 houses, many of which were built from wood. Around 90 per cent of the city's buildings were within 3km of the impact zone.

Thermal radiation
Around 50 to 60 per cent of people within 2km of the hypocentre suffered from excessive scar tissue because of burns to the skin. While burns were worse in the victims that were closest to the bomb, even 2km away the temperature was still sufficient to cause paper to ignite.

Hiroshima before and after bomb, aerial view

PHOTO: GETTY ILLUSTRATOR: PAUL WESTON

Hiroshima as it happened

Bomb dropped
At 8.15am, Enola Gay drops Little Boy on Hiroshima. A total of 10 per cent of its 64kg of uranium-235 undergoes nuclear fission.

6 August 1945

Fireball
The Little Boy nuclear bomb emits a 280m fireball across the city, increasing the surface temperatures up to a scorching 4,000°C.

1 second later

Expansion
The sudden rise in temperature expands the air. Atmospheric pressure reaches 19 tonnes per square metre. Almost every structure collapses.

Pressure plunge
Air pressure near the hypocentre plummets from high to low. This causes air blowing out from the hypocentre to reverse, sweeping winds towards the centre with tremendous force.

Poison rain
Black rain falls, showering the west of the city in dark droplets of mud, dust, soot and radiation from the mushroom cloud.

30 minutes later

Much of the radiation took the form of gamma rays, but the major damage came from the 10 per cent that was made up of neutrons. These had the potential to cause more damage to body cells.

Half an hour after the explosion, black rain fell. The iconic mushroom-shaped cloud of the explosion drifted northwest, showering western Hiroshima in dark droplets of mud, dust, soot and radiation. Dead fish floated to the surface in ponds and rivers where the rain fell. Yet the survivors, burnt, parched and desperate, drank the rain.

Atomic aftermath

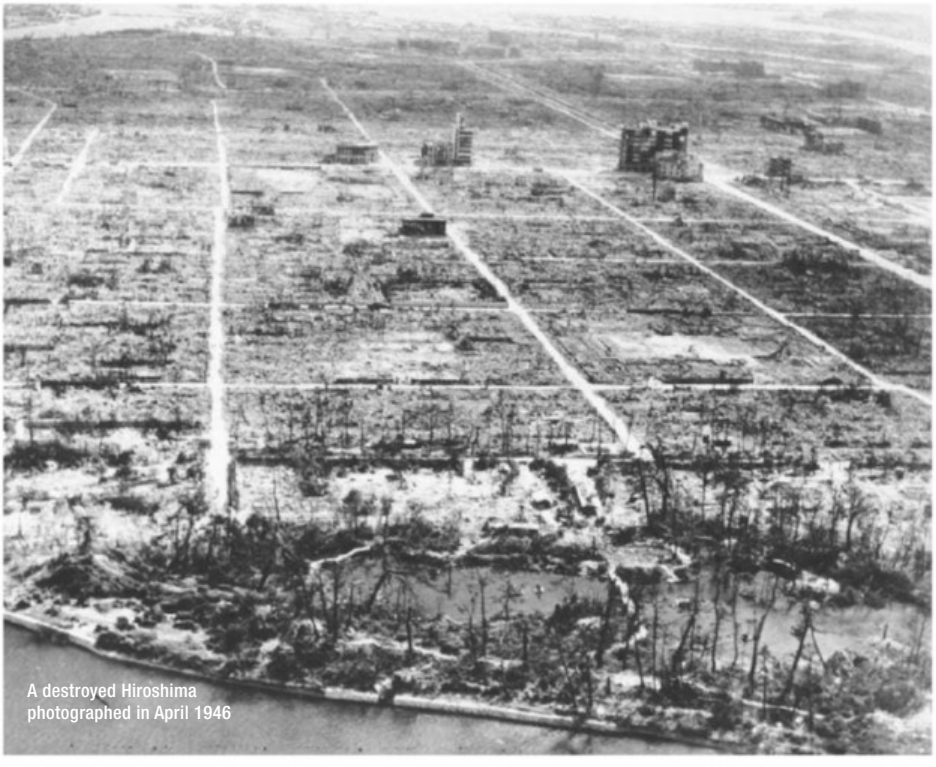
People started vomiting several hours later. After a few days, the first symptoms of radiation sickness were evident: fever, fatigue, bleeding in the gums and under the skin. It was all cell damage caused by radiation. Hair thinned and eventually just broke off. Diarrhoea, which for some lasted as long as three months, came from damaged cells lining the intestines. Those on the receiving end of the highest doses died within 10 to 20 days. The radiation also killed stem cells in the bone marrow so people couldn't make blood platelets, white blood cells or other key parts of the immune system. They bled out and couldn't fight infections. Many died within two months.

The closer a person had been to the hypocentre, the higher the radiation dose they'd received. The average dose for people within 2.4km of the bomb was 200mSv (millisieverts) – 100 times the level most people are exposed to in a year. Those closest to the bomb received 500mSv or more. Deaths from radiation sickness continued to rise for the next month, and didn't decline for another month after that – though it was hard to tell whether a death was from radiation, injuries or burns.

The survivors of Hiroshima were scarred mentally and physically. Around 50 to 60 per cent of those within 2km of the hypocentre suffered excessive scar tissue. Cataracts were common. Studies have found "statistically significant excess risks" in survivors for chronic hepatitis, liver damage, thyroid disease and cardiovascular disease. For those in the womb when the bomb hit, the effect on mental disability rose with increased radiation dose, along with impaired growth and development. If the physical pain didn't hurt survivors enough, they also suffered stigma. They were shunned and sometimes persecuted by their peers, who were fearful of their possible disease and radioactivity.

> "About three seconds after a blinding flash of light, a thunderous roar came down from the other side of the mountain. A big mushroom cloud could be seen growing, glinting brilliant silver under the Sun"
>
> **Hiroshima survivor**

There was more to come. "For those who survived the immediate effects of the atomic bombs, the most important long-term effect is an increased risk of cancer in those who were exposed to ionising radiation," says Prof Sarah Darby at the University of Oxford. Initial suspicions were that the radiation would cause genetic damage to sperm and eggs. But there has been no evidence of abnormal effects in children conceived by survivors after the bombing.



A destroyed Hiroshima photographed in April 1946

Illness
The first symptoms of radiation sickness appear, such as fever, fatigue, bleeding in the gums, hair loss and diarrhoea.
6-8 August 1945

Switch on
Power in some areas of the city is restored. A limited rail service resumes on 8 August.
7 August 1945

WWII ends
Fat Man, the second atomic bomb, is dropped on Nagasaki, ending WWII.
9 August 1945

Hope blooms
Canna flowers miraculously emerge in the Hiroshima rubble, giving residents hope.
September 1945

Fresh start
Typhoons hit the Hiroshima region, bringing in new soil and sand.
October 1945

Nature wins
Hiroshima's cherry trees bloom once again, less than one year after the bomb hit the city.
Spring 1946

"With their skin turned red, everyone seemed to walk like ghosts, with both hands reached out in front of them. Their skin, like the skin of potatoes, would stop at their nails and start to dangle from there"

Hiroshima survivor

A mother and her child sit in the rubble of Hiroshima in December 1945

PHOTO: GETTY, PRESS ASSOCIATION

The survivors were not so lucky. An increase in cancer diagnoses was first noted in 1956 and grew throughout the 1960s. By 2000, around 1,900 survivors were thought to have died from cancer linked to radiation. Thyroid and breast cancers were the most common, along with stomach and lung. Arguably the worst was leukaemia. The signs of this blood cancer began appearing in children two to three years after the bomb.

Studies conducted by the Hiroshima-based Radiation Effects Research Foundation (RERF) have concluded that between 1950 and 2000, 46 per cent of leukaemia and 11 per cent of other cancer deaths among survivors were due to radiation from the bombs. "These studies confirm, beyond any reasonable doubt, that an increased risk of cancer can occur without causing [obvious] tissue damage," says Darby.

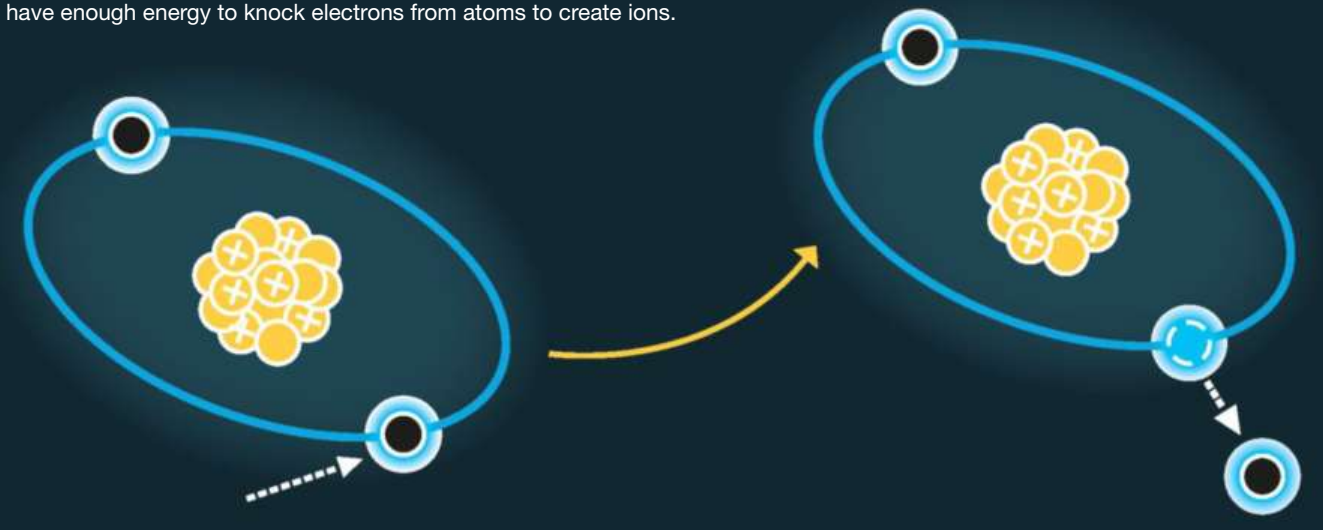
"The effect of radioactive black rain was definite and far-reaching," says Dr Aya Homei, a science historian at the University of Manchester. "The question of how far black rain reached has been a point of political contention in Japan, given that the answer to this has affected whether or not a survivor would be entitled to a government subsidy for their healthcare or not."

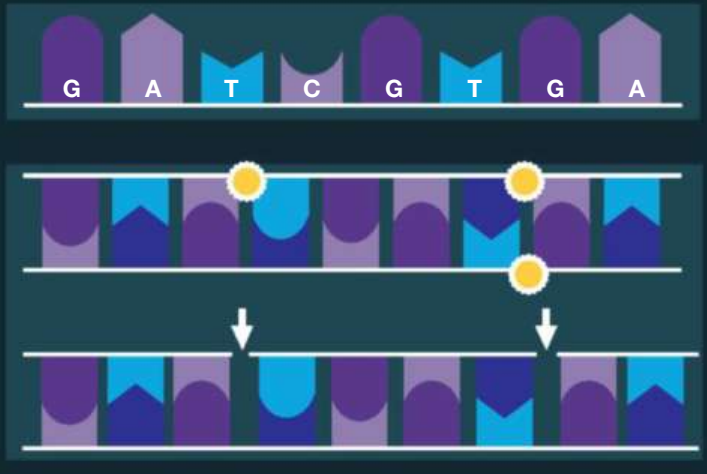
Scars on a Hiroshima survivor

RADIATION AND DNA How the bomb affected its victims' genes

1. Radiation waves

Gamma and neutron waves, like those emitted in the explosion of Little Boy, are types of 'ionising radiation'. This means that they have enough energy to knock electrons from atoms to create ions.



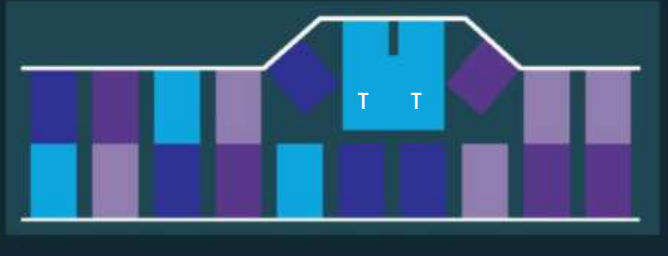


2. DNA damage

DNA contains four bases - cytosine, guanine, thymine and adenine. The ionised particles can cause breaks in the structure of DNA. Cells can repair some of these breaks, but they risk making mistakes during the repair. Breaks can occur across one or both strands. Cells find it much harder to fix breaks across double strands.

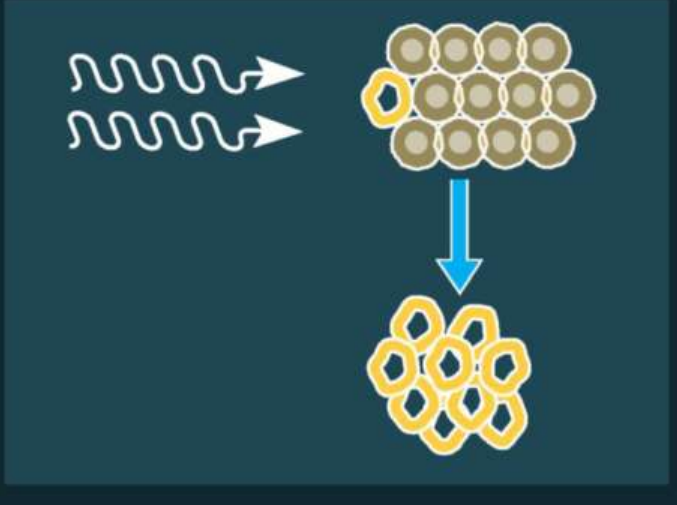
3. Code breaker

It is also possible for radiation to alter the genetic code directly. Gamma and neutron radiation can change one of DNA's bases into another, or can even make two bases stick together.



4. Cancer creator

The mistakes made by the broken DNA are called mutations. Sometimes, the mutations can be so bad that a cell no longer understands its instructions. Rather than repairing itself or self-destructing, it may multiply, which can lead to a tumour.



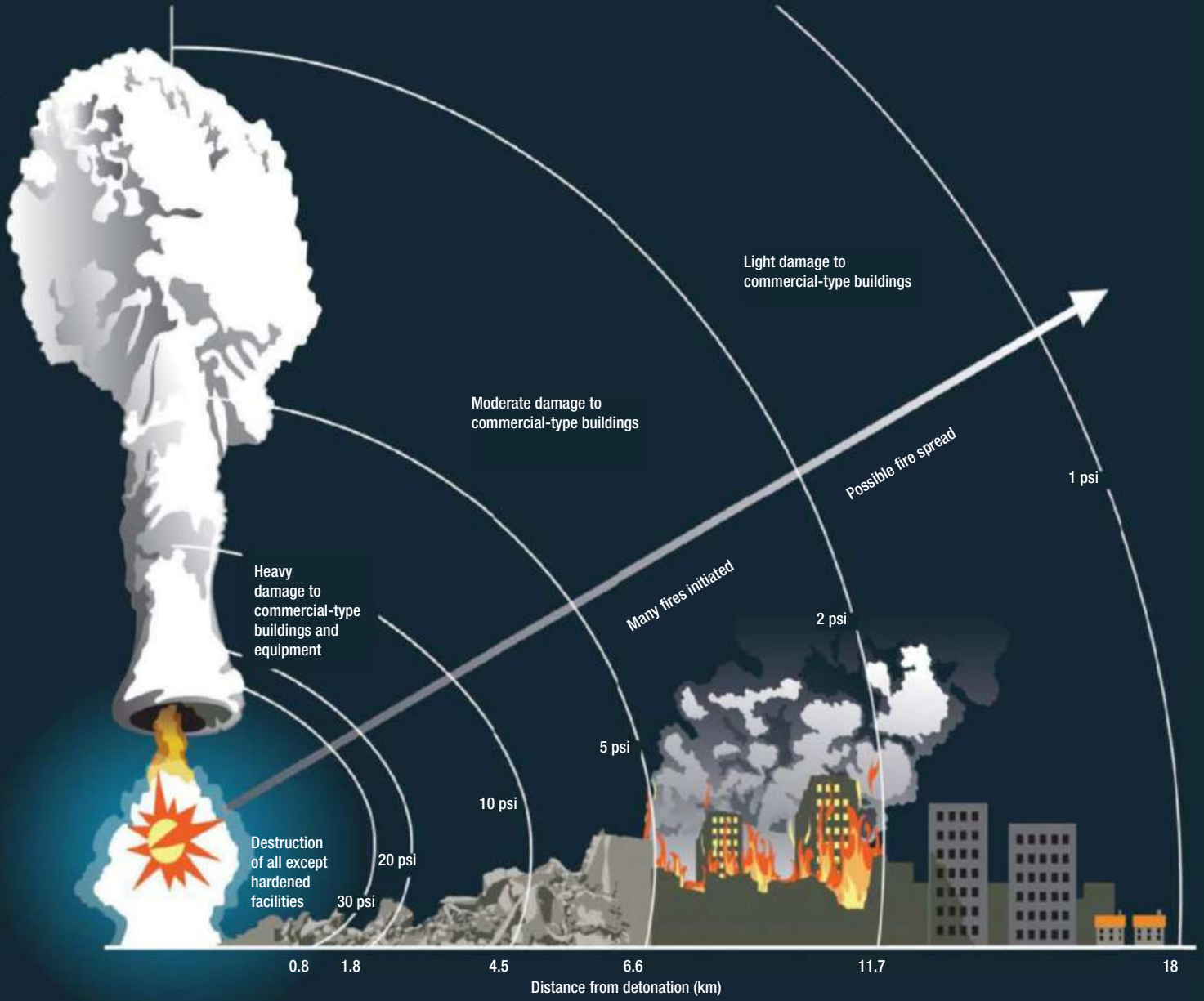
A modern bomb...

Today's weapons are capable of wreaking even more destruction than Little Boy

The bomb dropped over Hiroshima unleashed a punch equivalent to 15 kilotonnes of TNT. This was sufficient to destroy the city and claim thousands of lives. Today, technology has moved on and more destructive weapons have been developed. The most powerful nuclear weapon ever detonated was the Tsar Bomba, with a yield equivalent to 50 megatonnes of TNT. It was tested over the Arctic Sea in October 1961.

While many nuclear weapons have now been dismantled, a number of countries still possess them, including the USA, France, the UK, Russia, North Korea, Pakistan, Israel, China and India. Precise numbers of nukes are top secret. Below is a scenario in which a one megatonne bomb – up to 75 times the yield of Little Boy and roughly equivalent to the USA's B83 weapon – is detonated at a height of 2.2km.

One of the Royal Navy's Trident-class nuclear submarines



After effects
The US establishes the Atomic Bomb Casualty Commission to study effects of radiation on survivors.
1947

Cancer cases
Some children who were exposed to radiation from the bombs start developing signs of leukaemia.
1947 -48

Peaceful city
Hiroshima is designated a City for Peace by mayor Shinzo Hamai. This is a key event in the city's recovery.
1949

US exit
Japan becomes independent after US forces leave the country.
1952

Health scare
An increase in cancer diagnoses among survivors is noted, growing in number throughout the 1960s.
1956

Time bomb
Around 1,900 survivors are estimated to have died from cancer caused by the bomb.
2000

"Tests have shown that the radiation in an area exposed to the force of an atomic bomb will not be dissipated for approximately 70 years. Hiroshima will be a devastated area, not unlike our conception of the Moon, for nearly three-quarters of a century"

Dr Harold Jacobsen

Recovery

Two days after the bombing, Manhattan Project physician Dr Harold Jacobsen was quoted saying that nothing would grow in Hiroshima for 70 years. The earth was scorched and melted. Around 90 per cent of the city's buildings had been within 3km of the impact zone. The explosion wiped out 76,000 houses, along with some 80,000 people. Any flora or fauna in the area were incinerated.

Around a month after the bombing, just 800m from the centre of the explosion, red canna flowers sprouted in rubble of Hiroshima's wasteland. This seemingly miraculous event gave hope and courage to the survivors. Yet this isn't actually that surprising, says Prof Jim Smith at the University of Portsmouth.

It would take "an awful lot" of radioactivity to stop plants from growing, he says. In fact, it would require hundreds of times more than the levels at Hiroshima, which were relatively low when compared to a nuclear accident like the Chernobyl power plant, where flora and fauna have similarly recovered. "It would surprise me if there was a problem with any plant recolonising," he says. "The impact of the actual bomb itself would be much more environmentally damaging than the subsequent radiation."

On the night of 17 September 1945, the Makurazaki typhoon hit Hiroshima. It killed over 2,000 people and flooded large areas of the city. This natural disaster brought in new, radiation-free topsoil and sand from outside the region.

By spring 1946, Hiroshima's cherry trees were revived. By the summer, oleander flowers – known for their resilience and now the official flower of Hiroshima – were in bloom. As the city revived through further years of slow rebuilding, fruit and vegetables such as tomatoes and cucumbers were grown among the shacks multiplying in the city's midst. Crucially, 81 of the city's bridges survived, aiding recovery efforts. By the mid-1950s, Hiroshima's population had returned to its pre-war level.

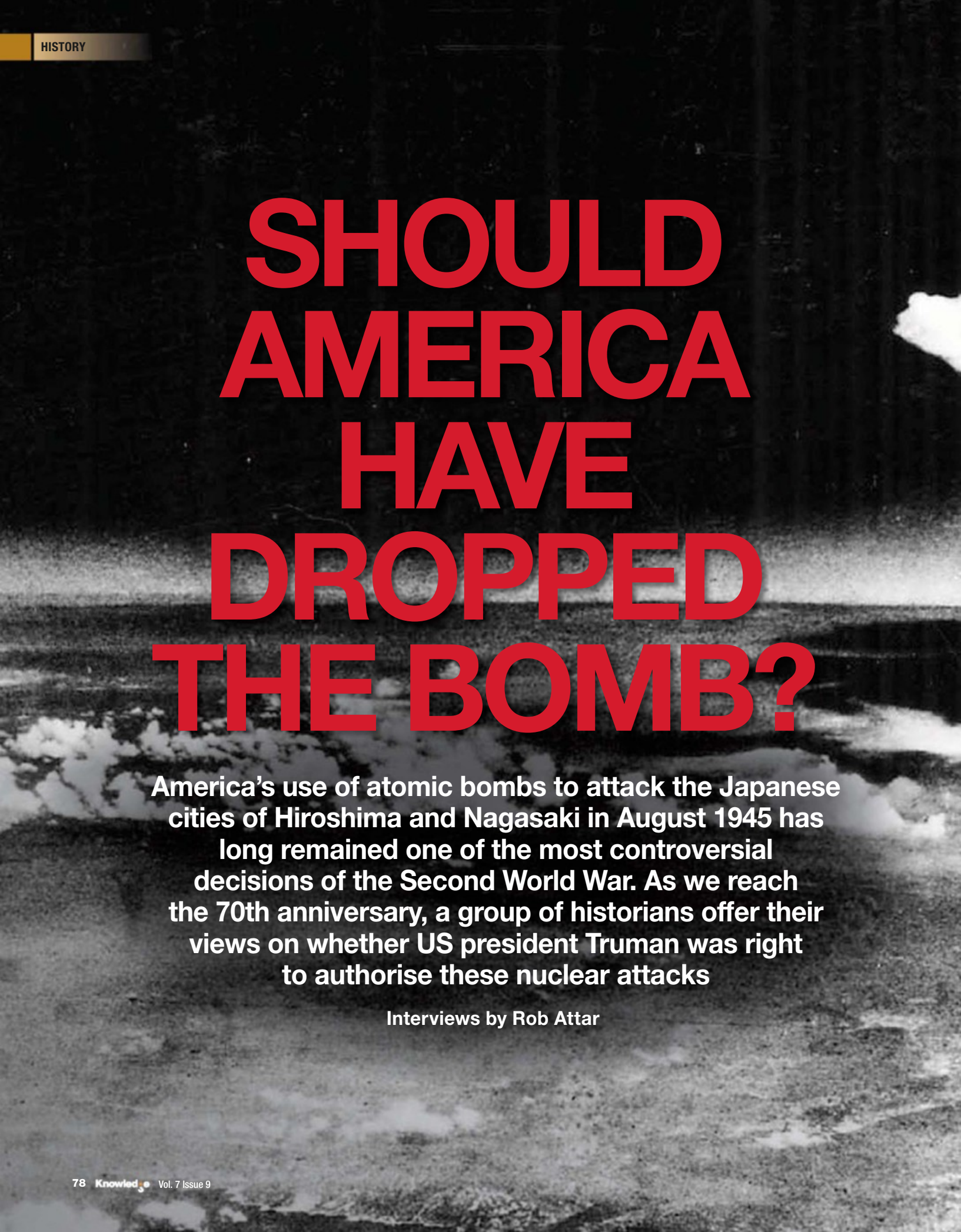

Canna flowers sprouted just one month after the bomb

Seven decades after the atomic bomb, Hiroshima is green once again. Many of its trees are gifts from donors from across Japan and overseas. Yet 170 trees are themselves survivors of the blast. These are known as 'hibaku jumoku' and consist of 32 different species. Just 370m from the blast centre stands a defiant weeping willow. Just like Hiroshima's human victims, the 'hibakusha', they live on. ■

MUN KEAT LOOI is an award-winning science writer and editor.


Today, Hiroshima is a thriving industrial city with a population of 1.1 million

PHOTO: GETTY, PRESS ASSOCIATION, ISTOCK ILLUSTRATOR: PAUL WESTON



SHOULD AMERICA HAVE DROPPED THE BOMB?

America's use of atomic bombs to attack the Japanese cities of Hiroshima and Nagasaki in August 1945 has long remained one of the most controversial decisions of the Second World War. As we reach the 70th anniversary, a group of historians offer their views on whether US president Truman was right to authorise these nuclear attacks

Interviews by Rob Attar

Scan this QR Code for the audio reader

The Japanese city of Hiroshima shortly after the US dropped the atomic bomb on 6 August 1945. The moral justification for the attack is still debated by historians today

"Yes. Truman had little choice"
says Antony Beevor

Few actions in war are morally justifiable. All a commander or political leader can hope to assess is whether a particular course of action is likely to reduce the loss of life. Faced with the Japanese refusal to surrender, President Truman had little choice.

His decision was mainly based on the estimate of half a million Allied casualties likely to be caused by invading the home islands of Japan. There was also the likely death rate from starvation for Allied PoWs and civilians as the war dragged on well into 1946.

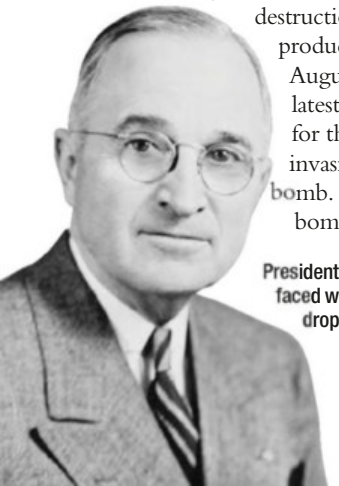
What Truman did not know, and which has only been established quite recently, is that the Imperial Japanese Army could never contemplate surrender, having forced all their men to fight to the death since the start of the war. All civilians were to be mobilised and forced to fight with bamboo spears and satchel charges to act as suicide bombers against Allied tanks. Japanese documents apparently indicate their army was prepared to accept up to 28 million civilian deaths.

ANTONY BEEVOR is a bestselling military historian, specialising in the Second World War. His most recent book is *Ardennes 1944: Hitler's Last Gamble (Viking, 2015)*

"No. It was immoral, and unnecessary"
says Richard Overy

The dropping of the atomic bomb on Hiroshima was justified at the time as being moral – in order to bring about a more rapid victory and prevent the deaths of more Americans. However, it was clearly not moral to use this weapon knowing that it would kill civilians and destroy the urban milieu. And it wasn't necessary either.

Militarily Japan was finished (as the Soviet invasion of Manchuria that August showed). Further blockade and urban destruction would have produced a surrender in August or September at the latest, without the need for the costly anticipated invasion or the atomic bomb. As for the second bomb on Nagasaki, that was just as unnecessary as the first one. It was deemed to be needed, partly because it was a different design, and the military (and many civilian scientists) were keen to see if they both worked the same way. There was, in other words, a cynical scientific imperative at work as well.



President Truman was the man faced with deciding whether to drop the atomic bomb on Japan

I should also add that there was a fine line between the atomic bomb and conventional bombing – indeed descriptions of Hamburg or Tokyo after conventional bombing echo the aftermath of Hiroshima. To regard Hiroshima as a moral violation is also to condemn the firebombing campaign, which was deliberately aimed at city centres and completely indiscriminate.

Of course it is easy to say that if I had been in Truman's shoes, I would not have ordered the two bombings. But it is possible to imagine greater restraint. The British and Americans had planned in detail the gas-bombing of a list of 17 major German cities, but in the end did not carry it out because the moral case seemed to depend on Germany using gas first. Restraint was possible, and, at the very end of the war, perhaps more politically acceptable.

RICHARD OVERY is a professor of history at the University of Exeter. He recently edited *The Oxford Illustrated History of World War Two (OUP, 2015).*

Nagasaki, after the bomb. Was this second nuclear attack necessary to force Japanese surrender or carried out for cynical, scientific reasons?

"Yes. It was the least bad option"
says Robert James Maddox

The atomic bombs were horrible but I agree with US secretary of war Henry L Stimson that using them was the "least abhorrent choice". A bloody invasion and round the clock conventional bombing would have led to a far higher death toll and so the atomic weapons actually saved thousands of American and millions of Japanese lives. The bombs were the best means to bring about unconditional surrender, which is what the US leaders wanted. Only this would enable the Allies to occupy Japan and root out the institutions that led to war in the first place.

The experience with Germany after the First World War had persuaded them that a mere armistice would constitute a betrayal of future generations if an even larger war occurred 20 years down the line. It is true that the radiation effects of the atomic bomb provided a grisly dividend, which the US leaders did not anticipate. However, even if they had known, I don't think it would have changed their decision.

ROBERT JAMES MADDOX is author of *Hiroshima in History: The Myths of Revisionism (University of Missouri Press, 2007)*

British captives. The US feared PoWs in Japan would starve if war dragged on

"No. Japan would have surrendered anyway"

says Martin J Sherwin

I believe that it was a mistake and a tragedy that the atomic bombs were used. Those bombings had little to do with the Japanese decision to surrender. The evidence has become overwhelming that it was the entry of the Soviet Union on 8 August into the war against Japan that forced surrender but, understandably, this view is very difficult for Americans to accept.

Of the Japanese leaders, it was the military ones who held out against the civilian leaders who were closest to the emperor, and who wanted to surrender provided the emperor's safety would be guaranteed. The military's argument was that Japan could convince the Soviet Union to mediate on its behalf for better surrender terms than unconditional surrender and therefore should continue the war until that was achieved.

Once the USSR entered the war, the Japanese military not only had no arguments for continuation left, but it also feared the Soviet Union would occupy significant parts of northern Japan.

Truman could have simply waited for the Soviet Union to enter the war but he did not want the USSR to have a claim to participate in the occupation of Japan. Another option (which could have ended the war before August) was to clarify that the emperor would not be held accountable for the war under the policy of unconditional surrender. US secretary of war Stimson recommended this, but secretary of state James Byrnes, who was much closer to Truman, vetoed it.

By dropping the atomic bombs instead, the United States signalled to the world that it considered nuclear weapons to be legitimate weapons of war. Those bombings precipitated the nuclear arms race and they are the source of all nuclear proliferation.

MARTIN J SHERWIN is co-author of *American Prometheus: The Triumph and Tragedy of J Robert Oppenheimer (Atlantic, 2008).*

"Yes. It saved millions of lives in Japan and Asia"

says Richard Frank

Dropping the bombs was morally preferable to any other choices available. One of the biggest problems we have is that we can talk about Dresden and the bombing of Hamburg and we all know what the context is: Nazi Germany and what Nazi Germany did. There's been a great amnesia in the west with respect to what sort of war Japan conducted across Asia-Pacific. Bear in mind that for every Japanese non-combatant who died during the war, 17 or 18 died across Asia-Pacific. Yet you very seldom find references to this and virtually nothing that vivifies it in the way that the suffering at Hiroshima and Nagasaki has been.

With the original invasion strategy negated by radio intelligence revealing the massive Japanese build-up on the planned Kyushu landing areas, Truman's alternative was a campaign of blockade and bombardment, which would have killed millions of Japanese, mostly non-combatants. For example, in 1946 the food situation would have become catastrophic and there would have been stupendous civilian deaths. It was only because Japan surrendered when it still had a serviceable administrative system – plus American food aid – that saved the country from famine.

Another thing to bear in mind is that while just over 200,000 people were killed in total by the atomic bombs, it is estimated that 300,000–500,000 Japanese people (many of whom were civilians) died or disappeared in Soviet captivity. Had the war continued, that number would have been much higher.

Critics talk about changing the demand for unconditional surrender, but the Japanese government had never put forth a set of terms on which they were prepared to end the war prior to Hiroshima. The inner cabinet ruling the country never devised such terms. When foreign minister Shigenori Togo was told that the best terms Japan could obtain were unconditional surrender with the exception of maintaining the imperial system, Togo flatly rejected them in the name of the cabinet.

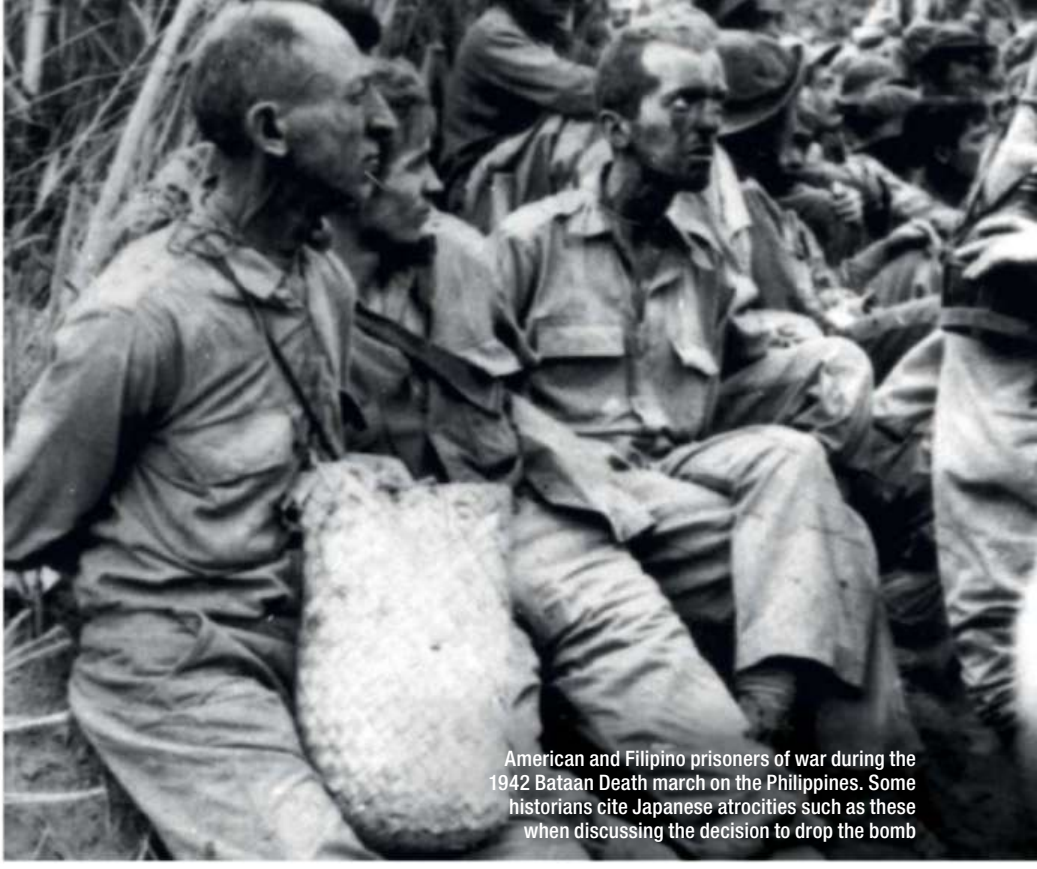
The fact is that there was no historical record over the past 2,600 years of Japan ever surrendering, nor any examples of a Japanese unit surrendering during the war. This was where the great American fear lay.

RICHARD B FRANK is a military historian whose books include *Downfall: The End of the Imperial Japanese Empire (Random House, 1999)*

"The fact is there was no historical record over the past 2,600 years of Japan ever surrendering"

Scarred victims of the bombing of Hiroshima. Some historians argue that using an atomic weapon on civilians amounted to a war crime

GETTY-ROGER VIOLLET/TIME & LIFE-GETTY/AP-PRESS ASSOCIATION



American and Filipino prisoners of war during the 1942 Bataan Death march on the Philippines. Some historians cite Japanese atrocities such as these when discussing the decision to drop the bomb

"No. Better options were discarded for political reasons"

says Tsuyoshi Hasegawa

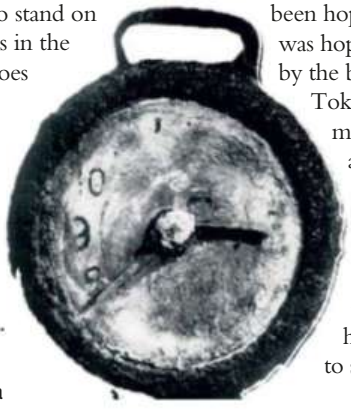
Once sympathetic to the argument that the atomic bomb was necessary, the more research I do, the more I am convinced it was one of the gravest war crimes the US has ever committed. I've been to Japan and discovered what happened on the ground in 1945 and it was really horrifying. The radiation has affected people who survived the blast for many years and still today thousands of people suffer the effects.

There were possible alternatives that might have ended the war. Truman could have invited Stalin to sign the Potsdam declaration [in which the USA, Britain and Nationalist China demanded Japanese surrender in July 1945]. The authors of the draft of the declaration believed that if the Soviets joined the war at this time it might lead to Japanese surrender but Truman consciously avoided that option, because he and some of his advisors were apprehensive about Soviet entry. I don't agree with revisionists who say Truman used the bomb to intimidate the Soviet Union but I believe he used it to force Japan to surrender before they were able to enter the war.

The second option was to alter the demand for unconditional surrender. Some influential advisors within the Truman administration were in favour of allowing the Japanese to keep the emperor system to induce so-called moderates within the Japanese government to work for the termination of the war. However, Truman was mindful of American public opinion, which wanted unconditional surrender as revenge against Pearl Harbor and the Japanese atrocities.

Bearing in mind those atrocities, it's clear that Japan doesn't have a leg to stand on when it comes to immoral acts in the war. However, one atrocity does not make another one right. I believe this was the most righteous war the Americans have ever been involved in but you still can't justify using any means to win a just war.

TSUYOSHI HASEGAWA is a professor of history at the University of California at Santa Barbara and the author of *Racing the Enemy: Stalin, Truman, and the Surrender of Japan (Harvard University Press, 2005)*



Time stopped for Hiroshima in August 1945, symbolised by a watch found in its ruins

GETTY/TOPFOTO

"Yes. The moral failing was Japan's"

says Michael Kort

Truman's decision to use the atomic bomb was the best choice available under the circumstances and was therefore morally justifiable. It was clear Japan was unwilling to surrender on terms even remotely acceptable to the US and its allies, and the country was preparing a defence far more formidable than the US had anticipated.

The choice was not, as is frequently argued, between using an atomic bomb against Hiroshima and invading Japan. No one on the Allied side could say with confidence what would bring about a Japanese surrender, as Japan's situation had been hopeless for a long time. It was hoped that the shock provided by the bombs would convince Tokyo to surrender, but how many would be needed was an open question. After Hiroshima, the Japanese government had three days to respond before Nagasaki but did not do so. Hirohito and some of his advisers knew Japan had to surrender but were not in a position to get the government to accept that conclusion. Key military members of the government argued that it was unlikely that the US could have a second bomb and, even if it did, public pressure would prevent its use. The bombing of Nagasaki demolished these arguments and led directly to the imperial conference that produced Japan's offer to surrender.

"There is no doubt that had the bomb been available sooner, it would have been used against Germany"

The absolutist moral arguments (such as not harming civilians) made against the atomic bombs would have precluded many other actions essential to victory taken by the Allies during the most destructive war in history. There is no doubt that had the bomb been available sooner, it would have been used against Germany. There was, to be sure, a moral failing in August 1945, but it was on the part of the Japanese government when it refused to surrender after its long war of conquest had been lost. ■

MICHAEL KORT is professor of social science at Boston University and author of *The Columbia Guide to Hiroshima and the Bomb (Columbia Press, 2007)*

THE FUTURE OF GADGETS
TECHHUB

EDITED BY **DANIEL BENNETT**

ON THE HORIZON

SUPER SLIMLINE SCREEN

LG Display unveils a prototype 1mm-thick OLED screen

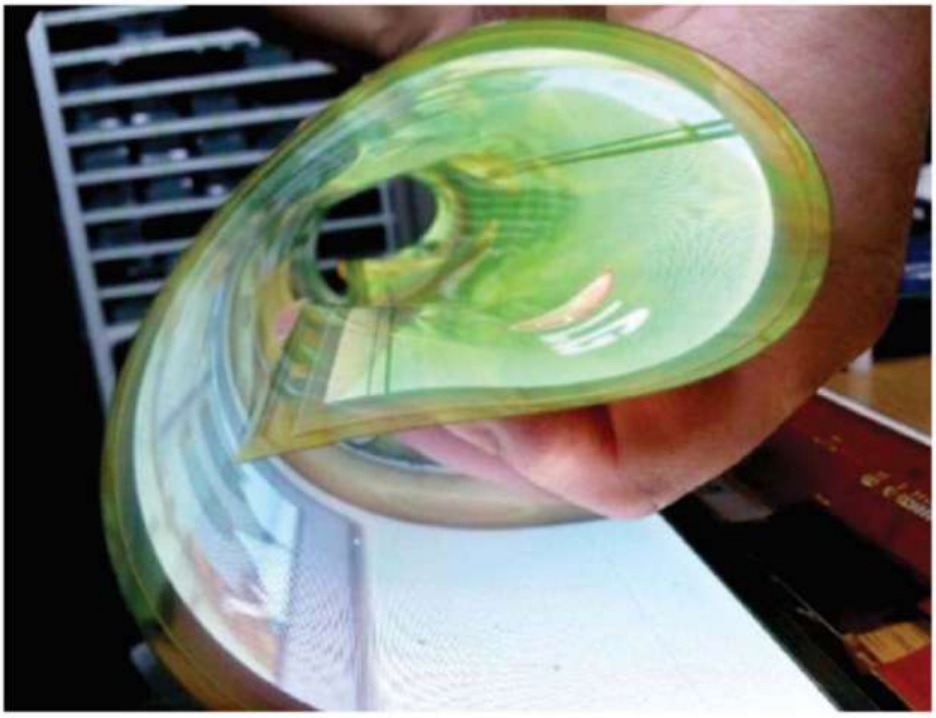
www.lgdisplay.com

The ongoing battle among technology companies to produce ever-thinner screens ramped up a notch in mid-May, when LG Display – part of South Korea's giant LG Corporation – held a press event at its headquarters in Seoul to show off a TV screen that's less than 1mm thick. The screen in question is only a prototype, and sadly there are no plans for it to go into mass production any time soon. But it's a clear indication of LG Display's belief that OLED (organic light-emitting diode) technology represents the future when it comes to TV screens, computer monitors and smartphone displays.

Although it's only risen to prominence in the past decade, OLED has a long history, dating back to the 1950s when French researchers observed that some organic materials are electroluminescent – that is, they give off light when subjected to an electric current. By making use of such materials, OLED screens obviate the need for the backlighting used in 'traditional' LCD/LED screens. This not only makes it easier to create slimmer displays, it also leads to improvements in energy efficiency, as well as offering a higher-contrast picture with deeper blacks. Motion response is also quicker than with LCD displays.

What's more, OLED displays can be printed onto a flexible plastic substrate, enabling the creation of screens such as this new prototype, which can be rolled up and carried around from one place to another – whether

The screen eliminates the need for awkward TV cabinets



OLED screens can be mounted on a flexible plastic substrate, enabling them to be rolled up when not in use

We've come a long way from the cathode ray tube…

that's from the boardroom to a meeting room or simply from the living room to the bedroom. When you want to use it, the display is then wall-mounted using magnetic strips.

OLED displays can use several different architectures, but all essentially consist of anode and cathode layers, with an organic emissive layer and (usually) a conductive layer sandwiched between the two, all mounted on a substrate. AMOLED (active-matrix OLED) screens also include a thin-film transistor layer to switch each individual pixel on and off. The exact specification of the screen that was exhibited in Seoul hasn't been made public, but it's likely to have been constructed using a polyethylene terephthalate (PET) substrate. That's the same kind of polyester-derived plastic used to manufacture fizzy drinks bottles: in other words, such screens needn't be hugely expensive to produce.

Currently, OLED is mostly used in mobile phones, digital cameras, sat-nav units and other portable tech. That's because the high-contrast views offered by OLED work better in bright, sunlit conditions, while OLED's major drawback – the lifespan of screens can't currently compete with that of LCD or LED displays – is less of an issue when it comes to devices that are used only intermittently. Motorola, Nokia, Samsung, HTC and LG all manufacture and sell smartphones with OLED/AMOLED screens, and the technology can also be found in Diesel and Fossil watches, and in some televisions made by Samsung, Sony and, of course, LG.

LG, though, appears determined to lead the field. In January, the company signed a long-term deal with Universal Display Corporation, which holds most of the patents relating to OLED technology, and at the event in Seoul, Sang-Deog Yeo, head of LG Display's OLED Business Unit, said: "OLED is the first display technology sector that Korea will dominate from the beginning." LG is already working to build an 'OLED alliance' with Chinese and Japanese manufacturers, and says it hopes to sell 1.5 million OLED TV panels in 2016.

The display revolution, it seems, will be televised.

RUSSELL DEEKS is a freelance science and technology journalist

PHOTO: AMAZON, GETTY, MARC HALL/NC STATE UNIVERSITY, FRAUNHOFER IVI

TECHOMETER

WHAT'S HOT

WINDOWS 10

Microsoft's next operating system was available as a free download at the end of July. Current Windows users will be able to upgrade for free for the first 12 months, and eagle-eyed users may have already spotted a new toolbar icon that lets them 'reserve' their copy. Early reports suggest that this version remedies the flaws of the much maligned Windows 8.

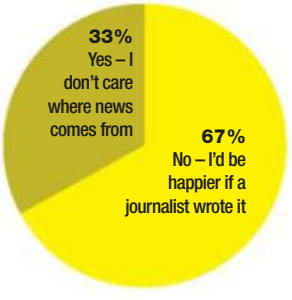
WHAT'S NOT

CASH

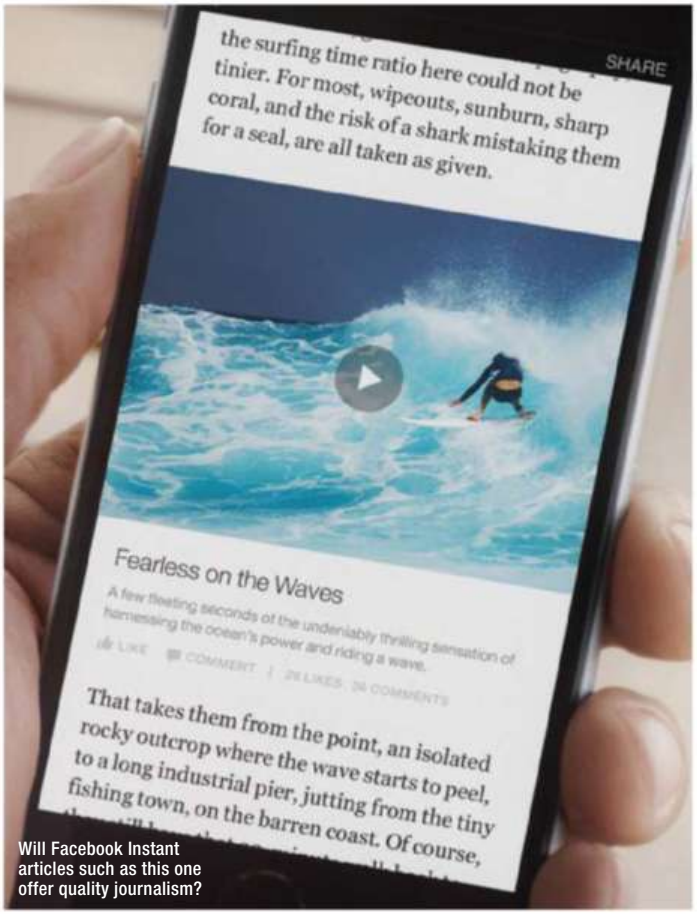
Cashless payment has overtaken use of notes and coins for the first time. The UK's Payments Council has revealed that cash was used for just 48 per cent of purchases last year, and predicts a further 30 per cent drop in the next decade. The Council suggests contactless payments for small sums, and dwindling numbers of phone boxes and parking meters, have tipped the balance towards cashless payments.

READER POLL

Would you trust news that was generated by robots?



ROBOT REPORTERS



Will Facebook Instant articles such as this one offer quality journalism?

Earlier this year, Facebook announced that it would work with several news organisations – including The New York Times, The Guardian, and the BBC – to place stories directly into users' news feeds. Stories published using Facebook Instant will load more quickly and keep the style of the original publisher, who will keep all the ad revenue the stories generate – at least for now. The deal, currently only a pilot but likely to be extended, shows how vital social media has become to news organisations, and is a clear sign of how the world of news is changing – and has been for a while.

When Google News launched in 2002, many saw it as a harbinger of the death of the newspaper. It had no editor, just an algorithm that selected news stories from online publications and displayed them according to an index of interestingness known only to Google. More recently, the likes of Associated Press and Yahoo! have been experimenting with computer-generated prose. Both use software from Automated Insights to generate stories about company financial results and sports reports – areas where the quality of prose is felt to be of secondary importance to the accuracy of the data.

Facebook Instant feels like simply another step towards a world in which news stories are written by programs, distributed by algorithms and read on social media. The only thing likely to remain are the familiar brands, so we can choose to have Guardian- or Sun-flavoured stories sprinkled through our kitten-filled Facebook feeds like the odd healthy prune in a bowl of Sugar Puffs.

So what's wrong with that? If the job news organisations do is better served by Facebook Instant and its complex algorithms, why worry? Well, one concern is that Facebook, Google et al see journalism as a sideline, a way of putting people in front of ads. It isn't their primary mission – so if it stops making them lots of money, they're likely to stop doing it. There's also a concern that what results is not actually journalism at all, because what a human news team produces is actually quite fragile and special. A well-written news story puts information in context, offers a voice to each side of an argument and brings the public new knowledge.

Of course, I would say that. I'm a journalist, and I want you to believe in it because it keeps me in work. But simple economics and our seemingly unquenchable desire to live in the eternal present mean you'll probably choose an app-generated story over my carefully crafted prose – at least for your daily news. But I don't think the AIs will be writing any of our in-depth features for a while yet. ■

BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

FROM THE LAB

Wheels on the bus go round and round thanks to new charging system

WHAT IS IT?

A high-capacity charger for electric buses that has been developed at Germany's Fraunhofer Society, which also gave the world the MP3.

WHY IS THAT A GOOD THING?

Using electric vehicles for public transport is problematic. On average, buses travel 400km (250 miles) a day; to charge an electric one, you either need to fill half the bus with enormous batteries, or keep taking it off the road to charge. The Fraunhofer chargers can be installed at a bus station, allowing the driver to charge up the vehicle while waiting for passengers to board.

HOW DOES IT WORK?

The driver manoeuvres the vehicle into position under a charging pole, which hooks up to a 'contact head' on the roof of the bus. It takes just 6.5 minutes to charge up specially developed high-capacity batteries. The system has been on test in Dresden since November 2014 and has been performing well.

Electric buses could help reduce smog in city centres

Q&A

YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service

LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

editorial-bbcknowledge@regentmedia.sg

Q

Which fish jump the highest out of water?

A The Atlantic salmon (Salmo salar) can jump up waterfalls 3.7m high, but in open water the highest jumpers are all much larger fish. Some rays and marlin can leap three metres out of the water, but both are beaten by the shortfin mako (Isurus oxyrinchus). This acrobatic shark has been observed making jumps as high as six metres! **LV**

A fear of water is an unfortunate phobia for a ray

PHOTO: OCTAVIO ABURTO

In Numbers

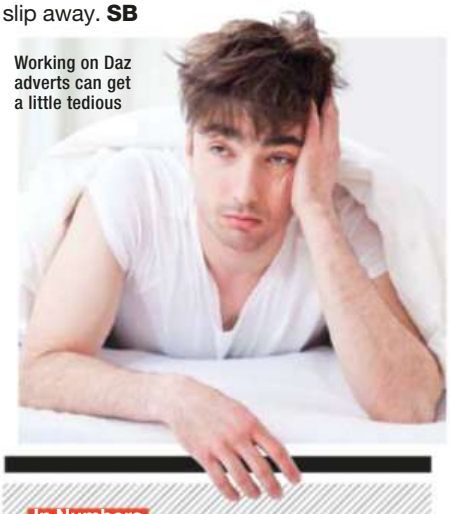
15

geckos were filmed playing during a 30-day space mission. It's an unusual observation as lizards don't tend to exhibit this behaviour

Why do we forget our dreams so quickly?

A Psychologists still don't understand the true function of dreaming. However, it almost certainly relates to memory, either by helping to consolidate the day's events or enabling us to forget unwanted detail so we don't become overloaded. In this case, recalling our dreams might not be helpful. During vivid dreaming, serotonin and noradrenaline levels are low and this might affect recall.

But perhaps the main reason is that most of our waking memories make sense and are interlinked. When I try to remember what I had for breakfast today, I can link that to memories of getting up, feeding the cats and lots of other small events. But dreams are usually illogical and their events are unrelated. So when we try to recall them, we cannot follow a sensible thread and the previously vivid details just slip away. **SB**



Working on Daz adverts can get a little tedious

In Numbers

2.3 billion

cups of coffee are drunk in the world every single day – yearly consumption has increased by 2.5 per cent since the start of the millennium

Why do dogs and cats like being stroked?

A Stroking a cat or a dog causes the hormone oxytocin to be released in both the owner and the animal, which lowers blood pressure and reduces anxiety. It also promotes a feeling of wellbeing and love in humans, so it's reasonable to assume that animals experience comparable feelings as well. But why has such a response evolved? One theory is that the domestication of animals originally offered a huge survival advantage to both humans and their pets. Humans deliberately selected the friendliest offspring from each litter, so each generation of animals grew more responsive to human contact. Plus, early humans who were animal lovers were best able to take advantage of guard dogs and pest-exterminating cats. Over time, humans and animals have co-evolved to enjoy each other's company. **LV**

You don't know where my head has been…

Do animals from different regions speak the same language?

A It seems so. Most animals don't have a very complex vocal language to begin with, and the patterns of grunts and growls that they use to express different emotional states are all hard-coded into their genes. Some studies have found that whales, dolphins, bats, hummingbirds and even cows develop regional differences, a bit like an accent or dialect. But it's hard to be sure if animals from different populations genuinely don't understand each other. It may be that the different vocalisations are just markers that help identify which animals are 'not from round here' and therefore should be treated more suspiciously. **LV**

The annual meeting of the Grass Appreciation Society was getting off to a promising start

PHOTO: ISTOCK X4, GETTY, GOOGLE EARTH X2

Hold on, lads – we need to count to five first!

Is there any scientific truth in the 'five-second rule'?

A Not much. Numerous studies have shown that some bacteria is transferred to food as soon as it touches the floor. Bacteria don't sense food dropped nearby and then home in on it – they get glued on by moisture and grease when the food falls on top of them.

A 2014 undergraduate study at Aston University found that the amount of bacteria was higher on food left on the floor for 30 seconds, compared with food that was picked up quickly. But this research wasn't published in a peer-reviewed journal, so it isn't clear how significant these results are. Another unpublished study at Manchester Metropolitan University found that very sweet foods like jam are actually less likely to get contaminated, because bacteria can't grow in high concentrations of sugar.

But while the exact proportion of floor bacteria that gets transferred to dropped food is interesting, it doesn't have very much bearing on how safe the food is to eat. We swim through a soup of bacteria everywhere we go. Bacteria are on every surface and we constantly pick them up with every touch. The hand that picks up your sandwich is probably just as contaminated as the kitchen counter or the floor. We are evolved to cope with these everyday germs with powerful stomach acid and an immune system to kill them off. Undercooking your chicken will give you food poisoning. Eating a chicken nugget off the kitchen floor probably won't. **LV**

PHOTO: OCTAVIO ABURTO

What are memcomputers?

Our brains are incredibly efficient, running on just 20W

A Despite awesome speeds, even the fastest computers are inefficient, as they use separate parts for processing and storing information. Memcomputers can do both on a single component. Neurones also exploit this trick, allowing our brains to work effectively on just 20W of power. Companies like Intel are working on the necessary technology, but commercial viability is still years away. **RM**

Is Google Street View being archived?

A Since April 2014, it has been possible to see previous versions of Street View images, some dating back to the start of the service in 2007. When historical views are available, a small clock face button appears on screen. Click that to display which images are available. For instance, the archive of London Bridge shows a non-existent Shard in 2008, a partially built one in 2012 and the completed tower in 2014. Fascinating! **GM**

Spot the difference, Google style

TOP TEN
LOUDEST SOUNDS (IN AIR)

1. Volcanic eruption
Sound intensity:
Up to 310dB

2. Atomic bomb
Sound intensity:
Up to 250dB

3. Earthquake
Sound intensity:
Up to 235dB

4. Space rocket launch
Sound intensity:
Up to 190dB

5. Gunfire
Sound intensity:
Up to 180dB

6. Fireworks
Sound intensity:
Up to 175dB

7. Dragsters
Sound intensity:
Up to 160dB

8. Jet aircraft taking off
Sound intensity:
Up to 150dB

9. Rock concert
Sound intensity:
Up to 140dB

10. Howler monkey
Sound intensity:
Up to 130dB

Q

Whatever happened to the problem of 'acid rain'?

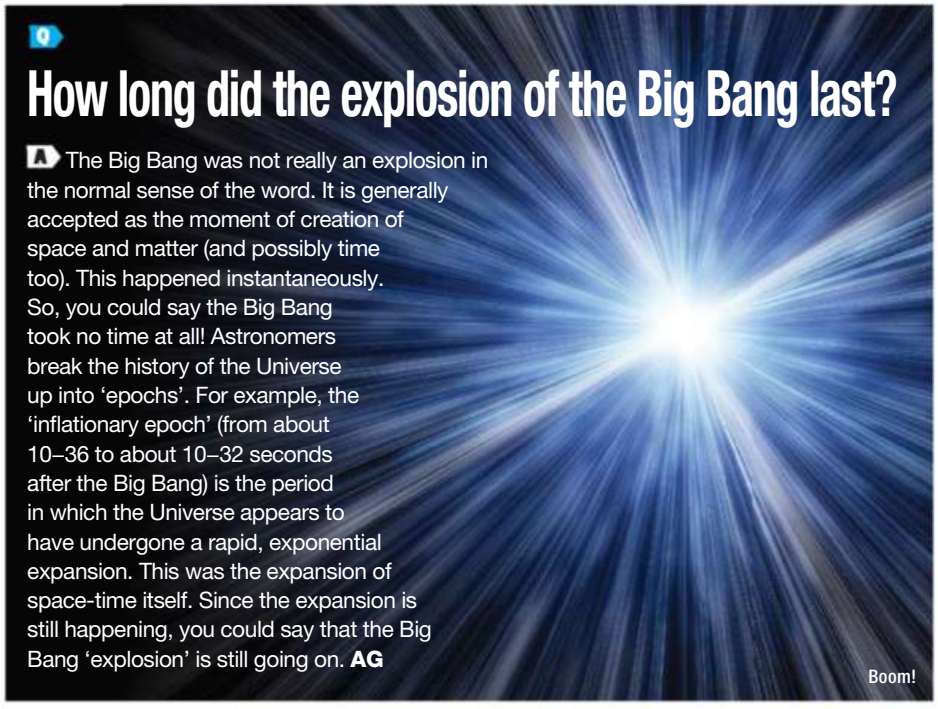
Thanks to improved international laws, sights like this are not as common as they once were

A During the 1970s, acid rain emerged as a major environmental issue, sparking rows between neighbouring countries. Scandinavian nations blamed Britain's power stations for creating sulphur dioxide and nitrogen-based airborne pollution that spread across the North Sea to mix with rain, causing acid damage to forests and lakes. Britain itself was affected, with a 1980 report highlighting contamination to lakes and rivers. Canada's environmental minister once described the pollution spreading from the US as an "insidious malaria of the biosphere". During the 1980s and 1990s, political pressure led to the introduction of international laws constraining the generation of the culprit compounds. Combined with wider use of cleaner forms of energy and improved standards of energy conservation, these measures led to substantial reduction in acid rain. In the US, the 1990 Acid Rain Program cut power station emissions of sulphur dioxide and oxides of nitrogen by over 70 per cent. Though still not entirely eliminated, the threat from acid rain is not the ecological threat it once was. **RM**

Q

How long did the explosion of the Big Bang last?

A The Big Bang was not really an explosion in the normal sense of the word. It is generally accepted as the moment of creation of space and matter (and possibly time too). This happened instantaneously. So, you could say the Big Bang took no time at all! Astronomers break the history of the Universe up into 'epochs'. For example, the 'inflationary epoch' (from about 10–36 to about 10–32 seconds after the Big Bang) is the period in which the Universe appears to have undergone a rapid, exponential expansion. This was the expansion of space-time itself. Since the expansion is still happening, you could say that the Big Bang 'explosion' is still going on. **AG**



Boom!

PHOTO: ISTOCK X9, GETTY, ALAMY, SCIENCE PHOTO LIBRARY, PRESS ASSOCIATION, HAKTARFONE/WIKI

Q&A

If swelling is bad, why does the body do it?

It's fine if a minor injury swells, but more serious ones can be problematic

A Swelling is a potentially useful response to injury or infection. It's caused by increased blood flow to the damaged area and an accumulation of white blood cells. These attack bacteria and remove dead cells before infection can set in. Even the pain associated with an inflamed injury is useful, because it encourages you to keep off it while it heals.

Our bodies have evolved a healing response that works tolerably well for minor cuts and bruises, but it can actually make a serious sprain or muscle tear worse because the increased fluid pressure cuts off the oxygen supply to the damaged tissues. The body actively regulates the inflammation response in an attempt to strike the right balance, but evolution isn't a perfect system. Our ancestors probably would have starved to death or been caught by predators before a major injury healed, so swelling would've been the least of their worries. **LV**

Is it safer to face backwards in a plane?

A Yes. In the event of a hard landing or minor crash, a rear-facing seat spreads the deceleration forces better across the body. A US Air Force study in 1957 found that passengers were seven times more likely to survive a crash if they sat facing backwards. But rear-facing seats have different stresses and would need to be made stronger and heavier, which would have an impact on aircraft efficiency. **LV**

Did you know?

Royal Observatory Greenwich's Burgess 'B' timepiece is the world's most accurate clock with a pendulum

For how long can a photon of light exist?

A If, as most physicists believe, these carriers of electromagnetic energy have no mass, they can't decay into anything else and so should last forever. It is theoretically possible they have a very tiny mass, but measurements suggest this is so low that photons have lifespans far longer than the current age of the Universe. **RM**

The lifespan of a photon is just a little longer than the film *Lawrence Of Arabia*…

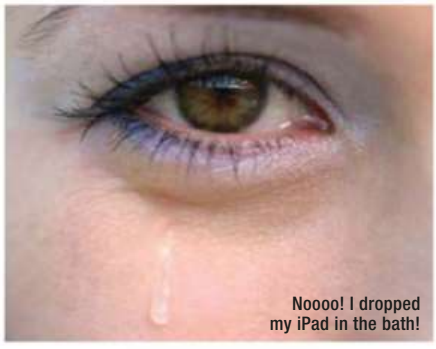
What is the biggest known star?

A Astronomers cannot be absolutely sure which of the known stars are the biggest or most massive. The largest known star by radius is generally accepted as UY Scuti, which is a red hypergiant star about 9,500 light-years from Earth. Its radius is probably 1,708 times the Sun's (over a billion kilometres). The most massive star is probably RMC 136a1, a Wolf-Rayet star about 165,000 light-years from Earth. It is believed the mass of RMC 136a1 is about 256 times the Sun's mass. **AG**

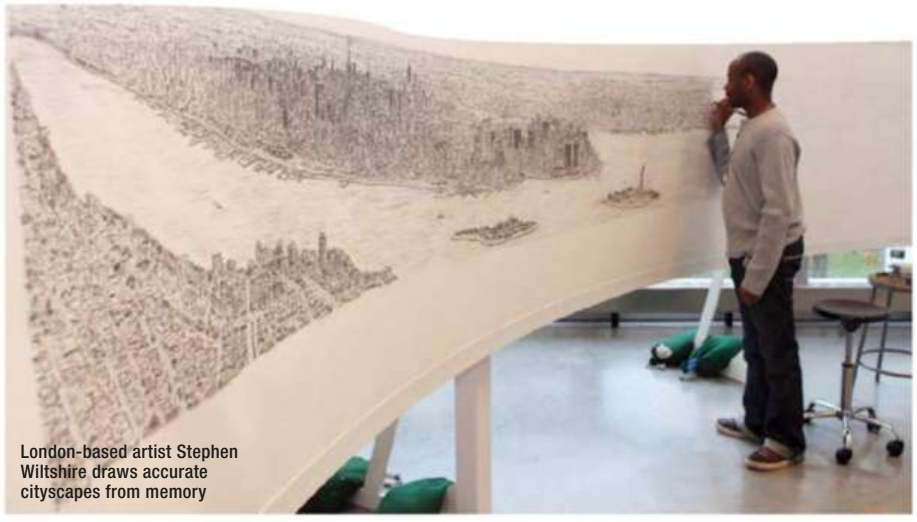
UY Scuti: still not as big as Simon Cowell's ego

Why do we cry when we're in pain?

When you were a helpless infant, crying was a distress signal to encourage your parents to make things better again. In adulthood, most wild animals suppress these signals because they don't want to announce their vulnerability to predators, or rivals of their own species. To some extent, this instinct persists with humans as well, which could be one reason why men tend to cry less than women. But compared to most mammals, we are a highly social species. However much it hurts your pride, crying in pain summons help and warns people of danger. Both of which are useful evolutionary traits. **LV**



Noooo! I dropped my iPad in the bath!



London-based artist Stephen Wiltshire draws accurate cityscapes from memory

Is eidetic memory genetic or learnt?

Eidetic memory in adults is very rare and thought to be inherited. Although sometimes referred to as 'photographic memory', this term is inaccurate because human brains are not like cameras and eidetic images are not really like photographs. Even so, when eideticers are briefly shown an unfamiliar picture they report 'seeing' a detailed mental image and can recall such tiny details as the number of windows in a street or petals in a flower. Also their eyes move as though they are scanning an image. Oddly, this extraordinary ability is not correlated with other memory skills nor with IQ. Between 2 and 10 per cent of young children experience eidetic imagery, but it tends to fade from about the age of six as they learn more efficient ways of dealing with information and develop verbal and autobiographical memory.

There are many claims, but no good evidence, that eidetic memory can be trained or taught. **SB**

Why are thunderstorms more common in the summer?

The science of how thunderstorms are triggered is still somewhat mysterious. Thunderstorms require the formation of clouds, inside which regions of positive and negative electric charges can accumulate. These lead to voltage differences so big – around 400,000V per metre – that electrons are stripped off the molecules within the cloud, forming violent electric flows we see as lightning.

Thunderstorms are more common during summer because the necessary conditions occur most readily when there's plenty of heat. Heat triggers convection, in which air becomes hotter, less dense and rises up from the surface. Plus, air holds most moisture when it's warm. While the processes that form the electric charges are not fully understood, it's believed to involve the interaction of violently rising moist air and ice crystals at high altitude.

In the UK, suitable conditions occur on only around half a dozen days during the summer. **RM**

PHOTO: ISTOCK X2, BARCROFT MEDIA, GETTY X2, US NAVY

Q&A

MQ-4C: too cool for Amazon deliveries

What is the world's most sophisticated drone capable of?

A Some of the most sophisticated Unmanned Aerial Vehicles are to be found in the military. About a year ago, details emerged of the US Air Force's secret autonomous aircraft, the RQ-180. Its main purpose is for reconnaissance in hostile airspace where its stealth design evades enemy radar. It has a massive 40-metre wingspan, which is 10 metres greater than a Boeing 737. This drone can fly continuously for 24 hours with a range of up to 2,500km. Its sensing and imaging equipment is based on radar and it is thought to have infrared cameras too.

Another highly advanced drone is the MQ-4C Triton. This is also a surveillance aircraft and the US Navy is developing it as an aerial platform for coordinating reconnaissance across huge swathes of ocean. Its radar can survey an area almost the size of Brazil in one go. This is thanks to the craft's 18km cruising altitude, which also keeps it safely out of reach of most anti-aircraft missiles. It even has de-icing and lightning protection tech. **GM**

How much does a parent's behaviour influence a child's?

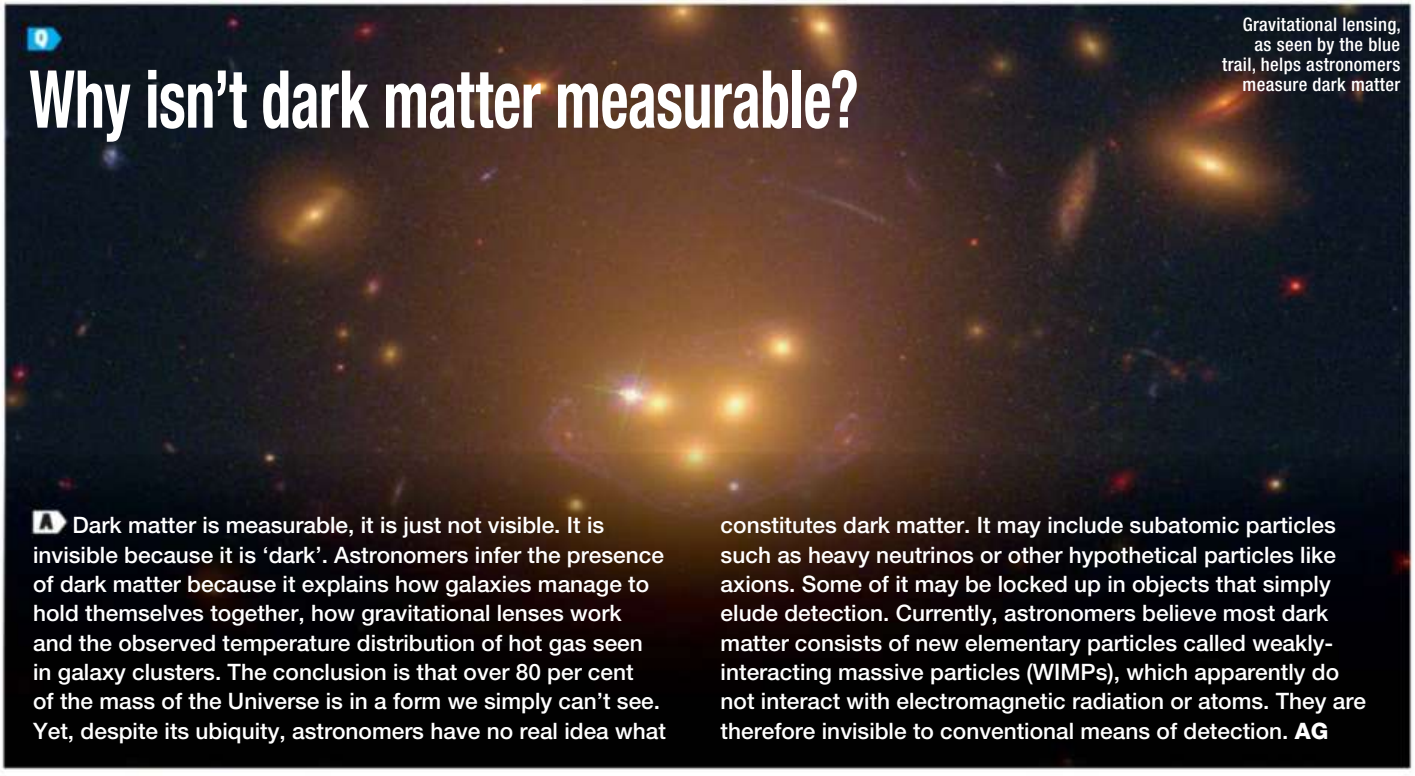
PHOTO: DURHAM UNIVERSITY, GETTY, PRESS ASSOCIATION

A A lot. But parental influence is only one factor and it interacts in complex ways with genes and the wider culture of school, the media and other children. Some new parents believe they can mould their children as they wish and then have a rude awakening when they discover the child's inherited potential takes them in totally different directions. At the other extreme, some think they can get away with poor behaviour and dreadful parenting techniques. One important factor is how the parents behave with each other and whether the whole family functions well. Children do better in stable families where their parents are not often arguing or being unkind to each other. But all these effects are complicated by the fact that children can influence their parents too. Plus, the same parental behaviour may have larger, smaller or completely different effects on children with different temperaments. So although we can be sure that parental behaviour is important, we cannot easily disentangle it from all the other inter-related effects. **SB**

How do fans make you feel cooler?

A As long as the air blowing past your face is cooler than your skin, some heat will transfer to the air molecules. The fan ensures the air molecules are moved out of the way before they have a chance to reach the same temperature as your face, and replaces them with other molecules that haven't been warmed yet. Similarly, sweating transfers some heat to the evaporated water molecules, and the fan prevents a humid layer from building up next to your skin that would slow down the rate of evaporation. **LV**

Why isn't dark matter measurable?



Gravitational lensing, as seen by the blue trail, helps astronomers measure dark matter

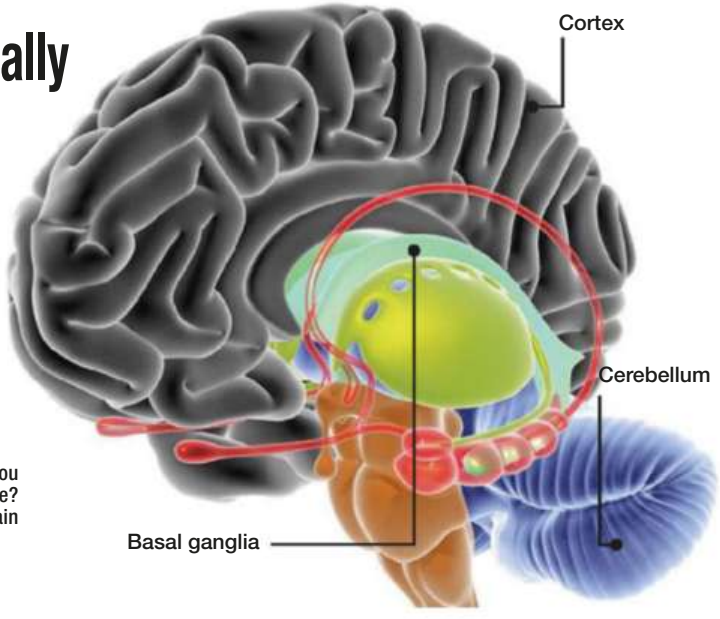
A Dark matter is measurable, it is just not visible. It is invisible because it is 'dark'. Astronomers infer the presence of dark matter because it explains how galaxies manage to hold themselves together, how gravitational lenses work and the observed temperature distribution of hot gas seen in galaxy clusters. The conclusion is that over 80 per cent of the mass of the Universe is in a form we simply can't see. Yet, despite its ubiquity, astronomers have no real idea what constitutes dark matter. It may include subatomic particles such as heavy neutrinos or other hypothetical particles like axions. Some of it may be locked up in objects that simply elude detection. Currently, astronomers believe most dark matter consists of new elementary particles called weakly-interacting massive particles (WIMPs), which apparently do not interact with electromagnetic radiation or atoms. They are therefore invisible to conventional means of detection. **AG**

How accurate are fitness trackers?

A Fitness trackers work by using accelerometers worn on your wrist, waistband or shoe to count your strides and convert that to an approximate measure of the distance travelled and the calories burned. Some also include altimeters, so they can give you extra credit for climbing stairs and hills. A 2014 study at Iowa State University compared them to more sophisticated laboratory equipment and found that most fitness trackers have error margins of between 10 and 20 per cent. Over a period of a week, that error adds up to about one day's worth of exercise. **LV**

Just *wearing* it doesn't make you fit, no matter how many you own

Is there really a fine line between love and hate?



Can't decide if you love or hate Marmite? Blame your brain

A In one sense, yes. When people see photographs of someone they love or someone they hate, two of the same brain structures are activated. The putamen, in the basal ganglia, is linked with contempt and disgust as well as choosing actions – obviously critical in both loving and hateful relationships. The insula, deep down in the cortex and involved in self-awareness and emotional processing, is also activated but there's a big difference: in romantic love, but not in hate, large parts of the cortex are deactivated. Perhaps rational judgment is needed for planning revenge or punishment, whereas romantic love makes us less rational about the perfect person we have fallen for. **SB**

The Thrilling Adventures Of Lovelace And Babbage

Nick Lane
Particular Books

19th century Britain witnessed a golden era of mechanisation and invention. But what if the Victorians had gone further. What if they'd invented a steam-powered computer? What if these computers could be programmed and put to work in number-crunching factories along the banks of the Thames? Perhaps telegraph lines could have hung over rooftops and linked the machines, sending information back and forth, connecting the world in a Victorian internet. Imagine how different the world would have been if such a machine had been invented.

But it was. Thanks to the eccentric genius of Charles Babbage and his trusty mathematical sidekick Ada, Countess of Lovelace, we came within touching distance of steam-powered computers and the Victorian information age.

In actuality, the machine was never built, but from this imaginary universe comes an imaginary comic book, one that supposes – in exquisite detail – what the adventures of Lovelace and Babbage might have looked like.

"Equations and technical babble from real letters between Lovelace and Babbage set up punchlines"

Sydney Padua's book is rich with in-jokes, warmth and charm. You are left in no doubt that this project was a labour of love for her – an ode to the marvellous, mysterious, non-existent Analytical Engine and its two imagineers. It's difficult not to be ignited by her enthusiasm.

While the adventures themselves are fictional, they all begin with a firm basis in truth, and Padua has a knack of spinning historical facts into playful storylines. Equations and technical babble from real letters between Lovelace and Babbage are used to set up punchlines. One comic has Babbage discover the unflattering comments made about him by Queen Victoria in her real-life diary. In another, Charles Dickens lines up to have his work spellchecked by the machine.

The foundations of truth make the jokes all the funnier, and Padua includes detailed but accessible footnotes to signpost the historical evidence for the reader. And all the way through the artwork is stylish and beautifully crafted.

There is so much to discover among Padua's 'concatenation of contraptions and labyrinthine of gears' that I'll treasure my copy for years to come.

HANNAH FRY is a lecturer in mathematics at *University College London*

Hardback Paperback

MEET THE AUTHOR

Sydney Padua

Where did Lovelace and Babbage first meet?
Babbage used to throw big parties where he'd demonstrate a model he'd built of the Difference Engine – his first machine. Someone who was there said that everyone else looked at it like savages looking at a mirror, but Ada Lovelace could see the beauty in the invention and understood its workings.

What did they work on together?
Babbage abandoned the Difference Engine in favour of the more complicated Analytical Engine, which was meant to do any kind of calculation. It had storage and data transfer, and it could be programmed – just like a computer. Babbage was obsessed with its mechanics, whereas Lovelace was more interested in the software side. With Babbage, she wrote an algorithm for the machine, considered to be the first computer program.

Why didn't Babbage ever construct his Analytical Engine?
Babbage was almost incapable of delegating work to others. His machine was the size of a steam engine and made of tens of thousands of gears, but he was trying to do it on his own. Ultimately it was just really, really hard – it's not a disgrace not to successfully build a mechanical computer in the 1840s!

If you could travel back in time, what would you say to them?
I would say: "It's okay, you were right about everything!" Lovelace died young and Babbage died miserable, so it's quite a sad story. I think they would be very, pleased to hear that they were right and everybody else was wrong!

How To Clone A Mammoth

The Science Of De-Extinction

Beth Shapiro

Princeton

Beth Shapiro's new book *How To Clone A Mammoth* is about as close as you could get to sitting down with a nice cup of tea to have a decent chinwag with a mate about resurrecting the woolly mammoth. First of all: spoilers! The mammoth is gone. You can't clone it, and you'll never bring it back. Instead, Beth Shapiro and colleagues have set their sights on an all-new, genetically modified creation: an elephant that can survive in extreme cold. It'll be woolly, so it will sort of look like a mammoth and that's good enough for Shapiro. But she isn't interested in resurrecting species – she hopes that elephants grazing the Siberian tundra will help restore an ecosystem last seen over 10,000 years ago.

Refreshingly, she replaces hyperbole with humour to guide the reader through the basics of de-extinction science. Some of the hurdles are swept aside a little blithely, and I would have liked a more critical eye at times. But this is in part a manifesto for her research, and that personal touch brings warmth. Shapiro's belief that a woolly elephant is inevitable, and the right thing to do, is infectious. I'm not fully convinced, but I am excited.

■■■■■

DR TORI HERRIDGE is a palaeobiologist at the Natural History Museum

Testosterone

Sex, Power, And The Will To Win

Joe Herbert

Oxford University Press

There are so many properties of testosterone you could write a book about them. Well, that's exactly what Joe Herbert has done. Herbert has a knack for including interesting examples to illustrate his points, such as showing how testosterone affects the economy by citing the dominance of males working at stock exchanges.

The issue is that, by actively focusing on the properties of testosterone and how it affects our world, the text comes across as very reductionist. It portrays complex and subtle human behaviours like dating as down to the actions of a single molecule. In doing so, it presents a worryingly simplified view of humans and their development. It's hard to see how this could be avoided, but any psychologists will likely find it grating.

One point: Herbert's use of quotes is often excessive. It makes it seem like he's not confident enough in his own writing, so has to rely on more established names. Given the subject of this book, that's either amusingly ironic or a brilliant meta-joke. Testosterone is a very good read on an interesting subject, but it may anger scientists. Again, pretty ironic.

■■■■■

DR DEAN BURNETT is a lecturer of neuroscience at Cardiff University

Spirals In Time

The Secret Life And Curious Afterlife Of Seashells

Helen Scales

Bloomsbury Sigma

Molluscs. Pretty dull squidgy things, right? Nope. This fascinating group has been happily diversifying since the Cambrian period to occupy every environment except the sky. Nonetheless, an entire tome on the shelly ones is a pretty enormous feat. While Spirals In Time is certainly not a book to attempt in one sitting, it's enjoyable to dip in and out of as Helen Scales's zeal for her subject is completely infectious.

One fascinating section in Spirals In Time outlines the mechanisms that give molluscs the patterned shells that have been prized by humans for centuries. Scales explains that scientists are still uncertain of the exact pigments that give seashells their colouration, and aren't sure why the markings are even created in the first place. Could it be to stop the animals 'losing their place' as they grow their shell? Or can it all be explained through computer algorithms? Clearly, we don't fully understand molluscs, yet issues like overfishing and acidification of oceans mean they need our help. Spirals In Time will raise appreciation for these creatures, and maybe you'll even think twice before sprinkling the slug pellets.

■■■■■

ALICE LIPSCOMBE-SOUTHWELL is the production editor at *BBC Focus*

Cakes, Custard And Category Theory

Easy Recipes For Understanding Complex Maths

Eugenia Cheng

Profile Books

Maths is easy. So argues Eugenia Cheng in her new book *Cakes, Custard And Category Theory*. You do, however, need to appreciate her definition of easy. Cheng, who can be found on YouTube making mobius strips out of bagels, is a lecturer in pure mathematics at Sheffield University.

The first half of the book discusses many interesting aspects of mathematical theory. It explains, for example, why a bagel is like coffee cup (topologically). The second half focuses on category theory. Category theory is to maths what maths is to everything else; it aims to explain the rules of maths and tries to tie together seemingly disparate areas of theory.

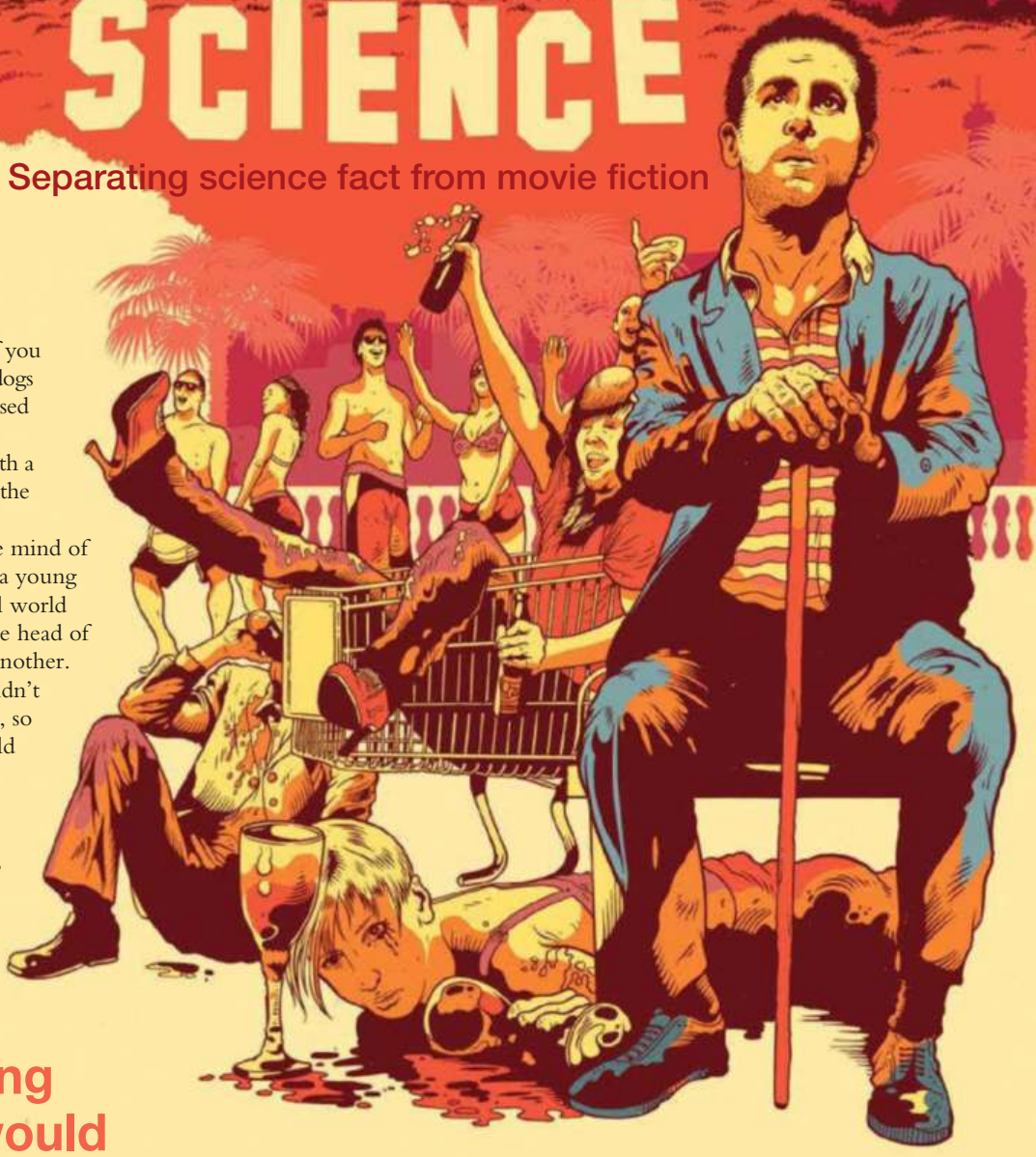
Many consider maths a difficult and dry subject. But the baking-based analogies and fun tangents used to demonstrate the various ideas in the book are entertaining and diminish the mental gymnastics that abstract maths can require. While it would be hard to claim that this book makes maths easy, it leaves you with an appreciation for it… along with a craving for a piece of iterated Battenberg cake.

■■■■■

TOBIAS JOLLY is a statistician and a columnist at *Significance magazine*

HOLLYWOOD SCIENCE

Separating science fact from movie fiction



Mind swaps in Self/less

My daughter asked me what would happen if you transplanted the brain of someone who likes dogs onto the body of someone who doesn't. It raised the spectre of head transplants; a topic, some would venture, that shouldn't be discussed with a 10-year-old, much less with one who was, at the time, eyeing up the family chainsaw.

In Self/less, I told her, medics transfer the mind of a cancer-riddled aristocrat into the body of a young man. But the closest we've come in the real world was in 1970 when a US surgeon stitched the head of one monkey onto the twitching corpse of another. This was met with stunned silence. They didn't attempt to join the spinal cords, I explained, so the monkey was unable to move but it could breathe… for eight days until the head was rejected and the monkey died.

I stroked my daughter's hair. Things have moved on, I reassured her. William Mathews, Chairman of the American Academy of Neurological and Orthopedic Surgeons, says that "technology and pharmaceuticals have evolved to make spinal cord fusion plausible and decrease the donor-recipient rejection." And in February this year, Sergio Canavero from the Turin Advanced Neuromodulation Group in Italy described how the first ever human head transplant might happen.

"The head, dangling from a harness, would be manoeuvred onto the neck of the donor"

First up, the body of a brain dead donor and the head of the recipient would be cooled to help preserve their cells. Teams of surgeons would then cut into the patients' necks, exposing blood vessels and the spinal cord. After colour-coding what connects with what, the spinal cords would be severed with an ultra-thin blade and the recipient's head, dangling from a specially constructed harness, would be manoeuvred onto the neck of the upright donor.

Polyethylene glycol would then be used to fuse the spinal cord back together. With everything else reconnected, the patient would be kept comatose for around a month while jolts of electricity delivered via electrodes would help strengthen cellular connections across the once severed spinal cord. All being well, a little while later, with the help of anti-rejection drugs, the patient would wake up and be able to literally feel and move their new body. "If Dr Canavero's research breaks through the frontier of spinal cord fusion, this will be the greatest achievement in medicine of the century," Mathews says.

The Italian man is doing it because he wants to help people whose bodies are failing, I explained to my daughter. She thought for a moment, then looked at me and said, "Yes, but will they still like dogs?" ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

ILLUSTRATOR: TIM MCDONAGH

Time Out

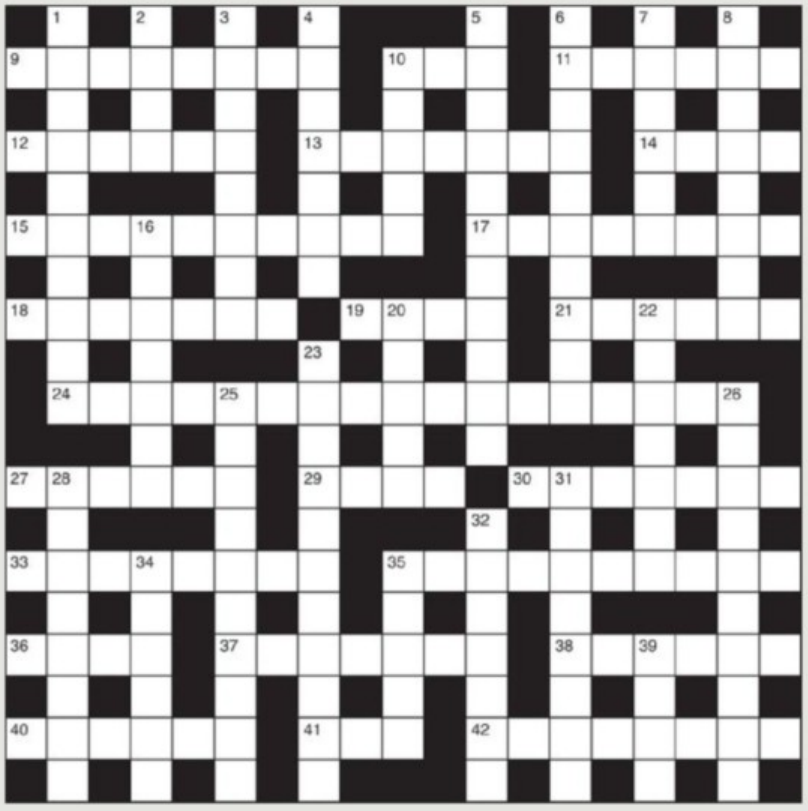
Crossword No.180

ACROSS

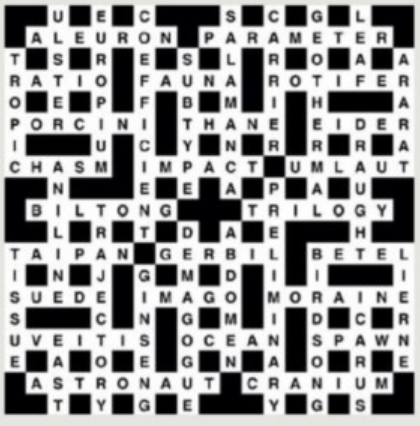
9 British artist to combine manganese ore (8)
10 Character providing pressure (3)
12 Article is definite relative to dissertation (6)
13 European then working with a fuel (6)
14 Yours truly takes subject of the forehead (7)
15 Cloudy astronomer of poor taste (4)
17 Parody edition (10)
18 Artisan caught by policeman with canine help (8)
20 Plaster forms part of stationery (7)
21 Thought aide was mad (4)
24 It is awful, getting old king to the river (6)
27 Mule's chic eminence affected by light in lab (17)
29 Lab equipment gets sharp response (6)
29 Local fellow has youngster (4)
30 Worry about party being a bore (7)
33 Sealed broadcast, then get drunk (8)
35 Permit starboard indicator to proceed (10)
36 Bird left with nothing on (4)
37 Red graduate volunteers facts first (7)
48 With small key, they activate lawn mower (6)
40 Right at home after lie to get some protein (6)
41 Very excited about whisky (3)
42 Resonant fellow follows programme (8)

DOWN

1 Calculations make him cattier, sadly (10)
2 Cat turns up with mother (4)
3 Nice seat set out for film buff (8)
4 A dimmer sort of mythological figure (7)
5 Father of medicine boxes with animal first (11)
6 Random order – it's a scotch (10)
7 Lacking in notes on nothingness (6)
8 Dutch land given to one PM (8)
10 Spike finds mine no different (5)
16 Iron construction contains food for orchestra (7)
20 Bit of training (5)
22 Divulging I like having sesame oil (7)
23 Courtesy bag distributed to smaller group (11)
25 Determined to get additive – resin – as a protective layer (10)
26 Neither has flourished in our reflection (10)
28 I'd cope – working with one school is irregular (8)
31 A cinema's arranged when he can't sleep (8)
32 Yarn about opening having space to exercise (7)
34 Mad aunt takes doctor somewhere cold (6)
35 Spirit of information, that is (5)
39 Variable answer, having to go back to philosophy (4)



SOLUTION TO CROSSWORD 177



The Last Word

How a 'crackpot' theory has just been proved correct

One century after a young German scientist tried and failed to convince others of his silly ideas about continental drift, it's his critics that have ended up looking silly.

Back in 1915, Alfred Wegener published The Origin Of Continents And Oceans, in which he presented evidence for what is now called plate tectonics. He hoped the book would spark interest among geologists. Instead, they seized on the obvious flaw in the idea: how can continent-sized slabs of rock slide around the Earth?

Wegener was still trying to convince his critics when he died in 1930, aged just 50. He'd put forward some ideas for ways of greasing the movement of continents, but they were dismissed as "utter, damned rot".

Now the mystery has been solved – and it turns out Wegener was on the right track. Using controlled explosions to trigger seismic echoes from deep within the Earth, a team of researchers in New Zealand has recently found that the plates of rock making up the crust sit atop pools of slippery, melted rock around 70-80km down.

So it seems that Wegener wasn't so crazy after all. Geologists had been forced to concede that point back in the 1960s, when analysis of sea floor rock showed continents do move apart – even if no one knew how.

What the new findings, published in Nature, really show is the danger of dismissing a theory just because it doesn't fit with current knowledge. This is the Argument from Omniscience: the assumption that just because we don't have an explanation, it means no-one will find one, ever.

People using the Argument from Omniscience can find themselves on shaky ground

"I can think of a host of intriguing theories that keep running into the Argument from Omniscience"

That sounds like arrogance to the point of lunacy. Yet you'll find plenty of otherwise rational people wheeling it out to dismiss ideas that they don't like, such as homeopathy. Before some of them start firing off emails demanding my immediate dismissal and execution, I should make clear that the evidence does not convince me either. But sceptics need to stop using the Argument from Omniscience.

Magnetism, radioactivity, aerodynamics, superconductivity… there's no shortage of phenomena whose reality once defied explanation. Radioactivity once caused huge concern because it seemed to violate the Law of Energy Conservation – until Einstein came up with his famous formula showing how mass can be converted into energy.

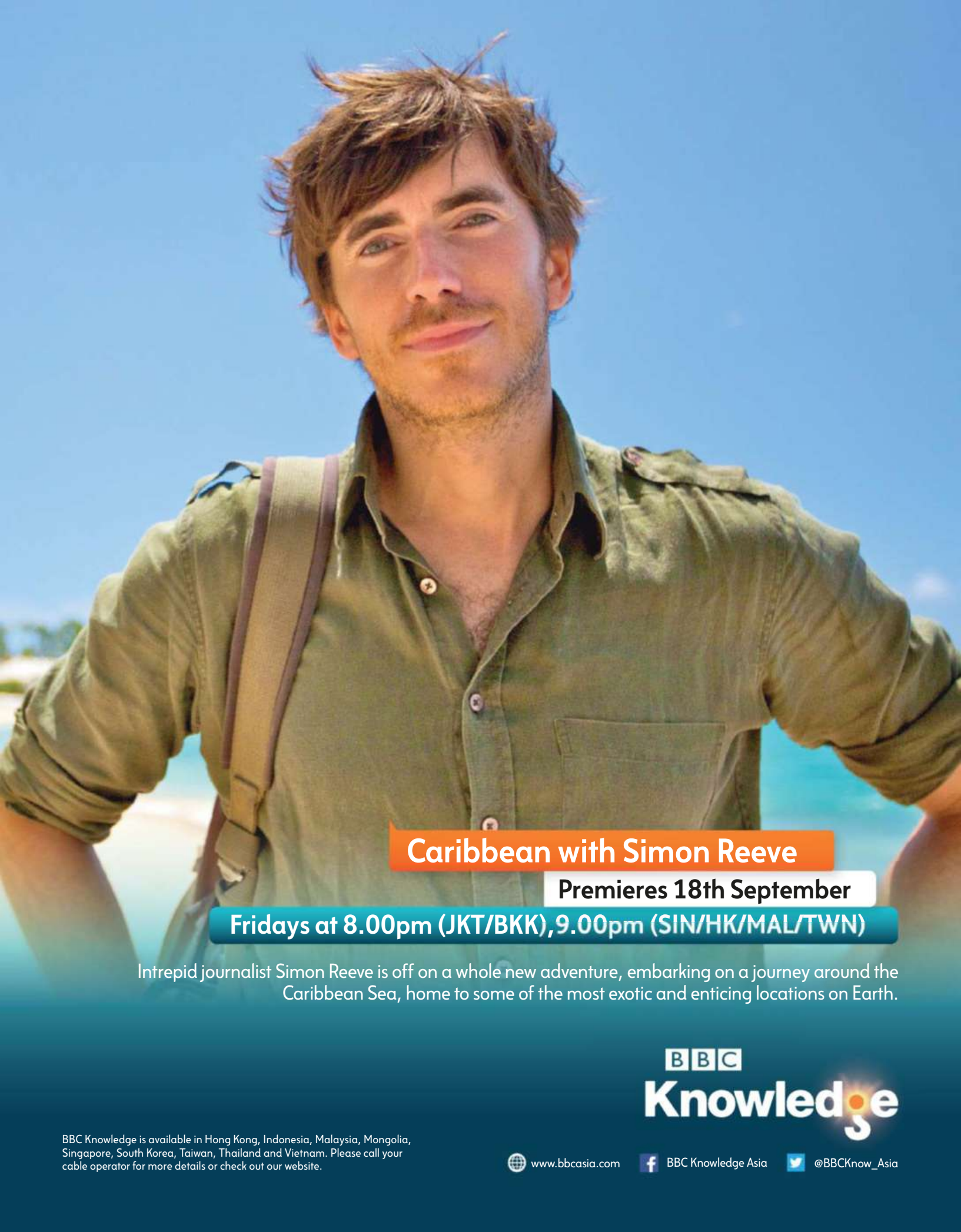
Indeed, some of the most intriguing phenomena in science, like anaesthesia, ball lightning and dark energy, are still not fully understood. Fortunately, hard evidence for these emerged fast enough to ensure researchers who take them seriously won't suffer the fate of Wegener. But I can think of a host of intriguing theories in everything from cancer therapy to cosmology that keep running into the Argument from Omniscience: science cannot currently explain them, so it never will.

There are better rules for judging new theories. For example, Ockham's Razor says that the more assumptions a theory makes, the less likely it is to be valid. And science populariser Carl Sagan advocated another rule of thumb: extraordinary claims require extraordinary evidence.

These rules are not always easy to apply, but they do have a solid basis in the mathematics of evidence – which the Argument from Omniscience doesn't. Of course we can't take every idea seriously; there just isn't enough time or money. But Wegener's belated vindication is a reminder that some astounding scientific advances emerge from ideas that are not entirely rock solid. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: DALE EDWIN MURRAY


Caribbean with Simon Reeve
Premieres 18th September
Fridays at 8.00pm (JKT/BKK), 9.00pm (SIN/HK/MAL/TWN)
Intrepid journalist Simon Reeve is off on a whole new adventure, embarking on a journey around the Caribbean Sea, home to some of the most exotic and enticing locations on Earth.
BBC Knowledge
BBC Knowledge is available in Hong Kong, Indonesia, Malaysia, Mongolia, Singapore, South Korea, Taiwan, Thailand and Vietnam. Please call your cable operator for more details or check out our website.
www.bbcasia.com
BBC Knowledge Asia
@BBCKnow_Asia

KOREA

Korea Incentive

A Place You Want to Be!

Enjoy a potpourri of unique cultural and historical experiences in the country that offers a fascinating blend of traditional and contemporary flavours.

Cultural tours, historical sites, medical and aesthetics tours, 24-hour shopping, amazing food, the K-pop phenomenon, and so many more await you!

KOREA
TOURISM
ORGANIZATION

Korea Tourism Organization and Korea MICE Bureau take pride in establishing Korea as the premier destination for MICE visitor.
For more information and assistance in holding your events in Korea, please contact KTO (Singapore office) at +65-6533 0441 or email: koreamice.singapore@gmail.com